United States
Department of the Interior
Geological Survey

# Ground Water Resources of the Qarahbulli Area, Tripolitania, United Kingdom of Libya

Prepared in cooperation with the Government of Libya
under the auspices of
the United States Agency for International Development
Mission to Libya

Open File Report

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# Ground Water Resources of the

# Qarahbulli Area,

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by

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and

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Ministry of Agriculture

Tripoli, Libya

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Ground-Water Resources of the Qarahbulli Area, Tripolitania, United Kingdom of Libya

by

William Ogilbee and Hadi Ali Tarhuni

## Abstract

The area studied comprises about 400 sq. km. along the southern coast of the Mediterranean Sea. The land surface of the area slopes generally northward to the sea, which is bordered by consolidated coastal sand dunes. Between the coastal dunes and a belt of semi-active dunes along the southern border of the area, is a zone of flatter land about 5 km wide interspersed with stabilized dunes. Some 6 ephemeral streams which rise on the Jabal Nafūsah drain northward across the area. These streams carry runoff to the sea in response to heavy rains - principally during the winter months. The climate is semiarid and is characterized by low precipitation (311 mm per year at Qasr al Qarahbulli), high evaporation, and wide temperature range.

Most present farming in this agricultural area is restricted to the flat-land zone between the coastal dunes and those farther inland. Agricultural development ranges from large-scale mechanized farming at Government-owned Agricultural Experiment Stations and a few Italian-owned farms to small hand-cultivated subsistence farms. Most of the crops cultivated are dependent on ground-water irrigation but rainfall is sufficient for cultivation of barley, grapes, olives and other tree crops.

The Qarahbulli area is underlain by northward dipping Quaternary and Miocene limestone, sand, and clay which overlie Mesozoic rocks. Quaternary sand and limestone aquifers yield most of the ground water currently used in the area. These aquifers at depths of 20 to 40 m. yield water of chemical quality that is generally suitable both for irrigation and domestic supply. Artesian water is also available from deeper Miocene aquifers, especially near El Guea.

Recharge to the aquifers in the Qarahbulli area is both by infiltration from local precipitation and by underflow from the south. Withdrawals by pumps and by flowing artesian wells of about 9 million cubic meters annually together with the natural discharge exceed the recharge, at least in the developed areas; consequently, the water levels in the developed areas are declining currently (1962) at about 0.1 to 0.2 m per year. The decline in head (hydrostatic pressure) of the artesian Miocene aquifers may be more than 0.5 m per year.

## Introduction

### Purpose and scope

This report summarizes the results of an investigation of the ground-water resources of the Qarahbulli 1/ area, Tripolitania. It is one of a number of reports on areal investigations made as examples of methods and techniques of hydrologic studies; also the areas have been selected so as to provide data for development planning.

1/ Transliteration of most of the geographic names used in this report conforms to the system adopted by the U.S. Board on Geographic Names, BGN/PCGN system. (U.S. Dept. of Interior, 1958). Some familiar names are left in their conventional forms.

The United Kingdom of Libya is currently undergoing a period of rapid economic development following the discovery of fairly large petroleum reserves. Much of the anticipated revenue from the exploitation of this important resource is to be used for further development of agricultural lands and water resources. However, informed individuals in Libya realize that water is among the chief limiting factors in the economic growth of the country.

The demand for additional water for agricultural use, industry and public supplies has resulted in an alarming decline of water levels in many of the developed areas. Much of the additional demand for water has arisen from the increasingly efficient pumps, increased availability of electric power, and improved markets for agricultural products. Also concern over the decline of water levels in a number of developed areas is now becoming widespread.

The present report is based on field work carried on intermittently by the writers and technical personnel of the Government of Libya during 1960-62. The report illustrates the application of established methods of field inventory of wells and of other hydrologic features and the compilation and interpretation of the resulting data. Information is given on depth to water, changes in water levels, depths of wells, chemical quality of water, and other pertinent hydrologic phenomena. Test drilling, geophysical studies, and pumping tests to determine hydraulic characteristics of aquifers, however, were not a part of the work.

## Location of the area

The area discussed in detail in this report comprises about 400 sq km (square kilometers) in the Province of Tripolitania (Wilāyat Ṭarābulus), Libya. The area lies between 13°30' and 14°00' east longitude and is bounded on the north by the Mediterranean Sea and on the south by 32°40' north latitude. Reference is made, however, to geologic and hydrologic conditions in the adjoining region that pertain also to the Qarahbulli area. The town of Qarahbulli, which is centrally located in the area, is about 60 km (kilometers) east of Tripoli (Ṭarābulus) along the coastal highway (fig. 1).

Figure 1.--Map of Mediterranean region showing location of area of study.

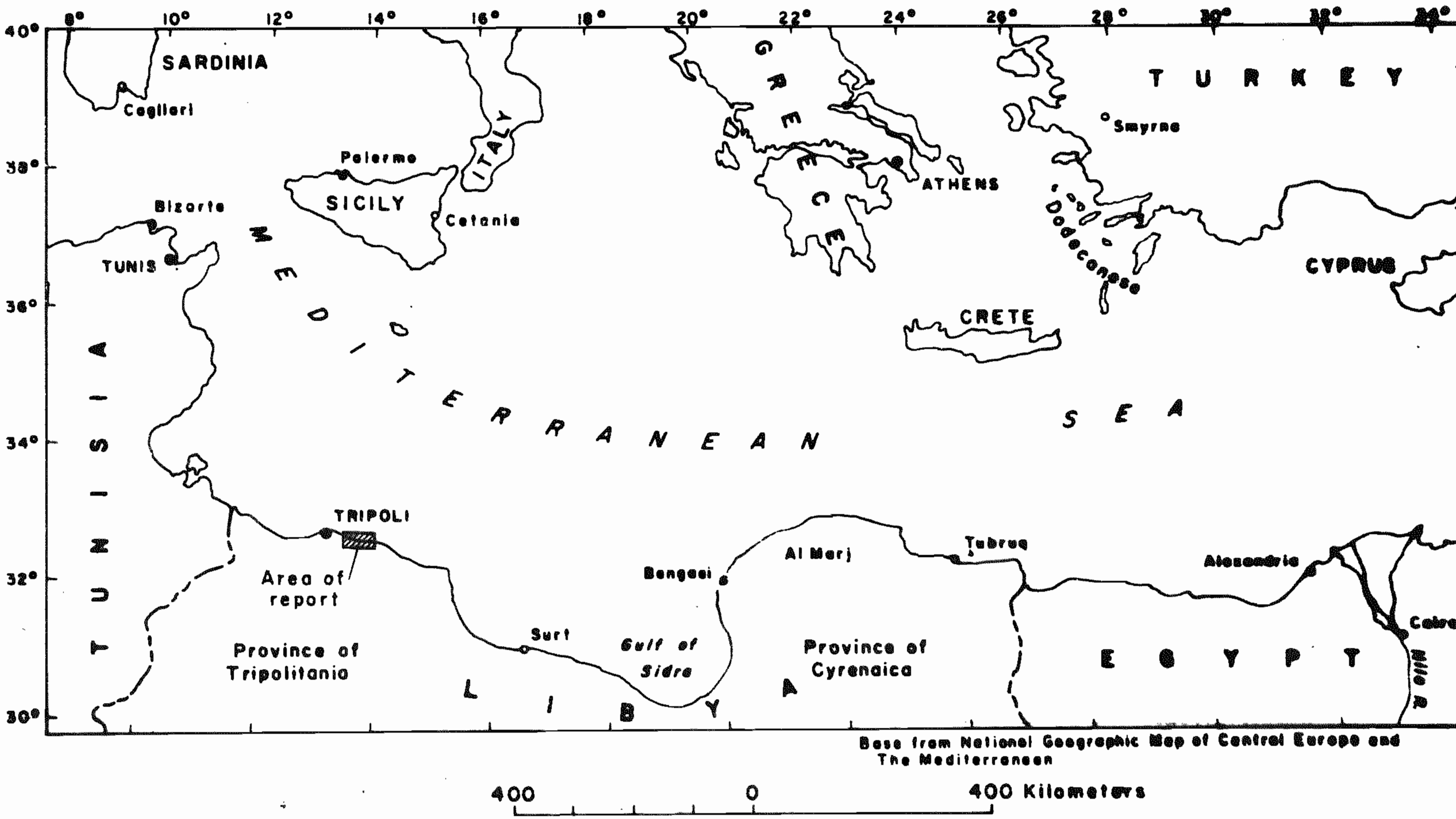


Figure 1.--Map of Mediterranean region showing the location of the area of study.

## Description of well-numbering system

The wells described in this report are assigned identification numbers based on the latitude and longitude of the well site. All of Libya is situated in north latitude and east longitude. Each well number describes the location of the well within rectangles of 1 minute or 5 minutes of latitude and longitude. The first unit of four numbers describes north latitude, and the second unit, separated by a hyphen, describes east longitude. This number is the latitude and longitude of the southwest corner of a rectangle that contains the well. This rectangle has dimensions of either 1 minute by 1 minute or 5 minutes by 5 minutes. The 5-minute rectangle is designated by the addition of the numeral 5 separated from the other units by a hyphen. The last number, also separated by a hyphen, represents the serial number of the well within the rectangle. For example, well 3244-1336-1 is the first well described in a rectangle 1 minute on a side and bounded by 32°44' and 32°45' north latitude and 13°36' and 13°37' east longitude (fig. 2).

Figure 2.--Map of the Qarahbulli area showing location of water wells.

Other well-numbering systems have been used in the past by the Italians and others. Many of these previously assigned numbers have been cross-indexed and are on file in the ground-water investigations offices of the Government of Libya.

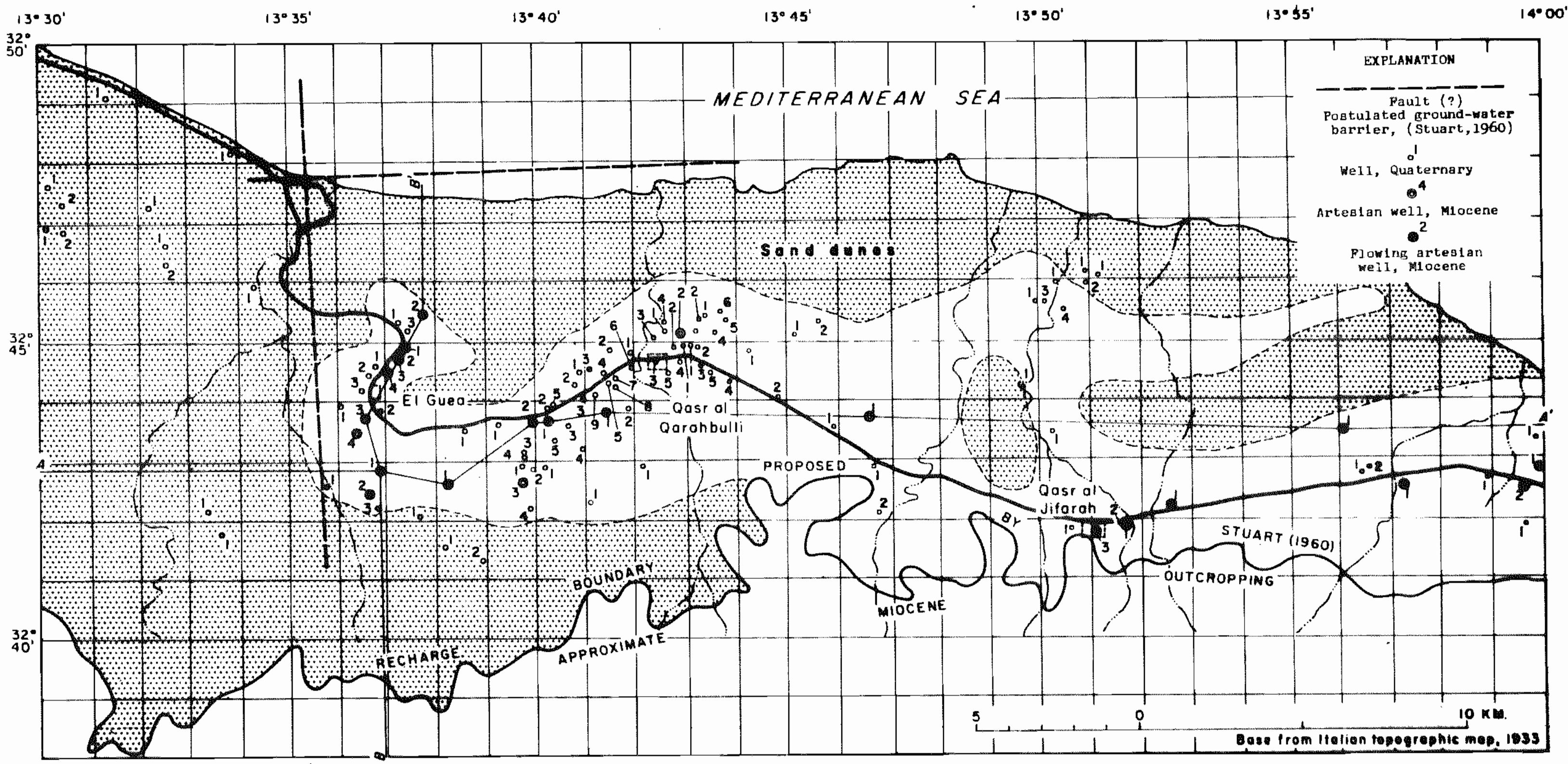


Figure 2.--Map of the Qarahbulli area showing location of water wells.

## Previous investigations

Information on the ground-water hydrology of Libya is not extensive, however, many significant contributions bearing on ground-water conditions were made by Italian geologists prior to 1940. The description of the geology of Tripolitania by Bernet (1912) was probably the first of these contributions. Parona (1915) discussed the formations exposed along the Tripolitanian coast in "Geomorphic Notes on the Gefara." Zacagna (1915) published a general report on geohydrologic studies in western Tripolitania and in 1919 published some measured sections along the Jabal escarpment. Desio (1939) compiled a geologic map of Libya. Floridia (1939) published measured sections and geologic map of the Homs (Al Khums) area.

In a more recent study, Borgognoni (1946) gave a generalized discussion of the ground water of Tripolitania. In 1955 Christie published on the geology of the Garian area. Hill (1960) published a paper on the ground-water resources of the Gefara. Cederstrom (1960) prepared a ground-water report on the Tripoli area that contains much information applicable to the Qarahbulli area. Stuart (1960) presented the results of pumping tests conducted in various parts of the Gefara. Vorhis (written communication) provided a good compilation and review of the geologic history of northern Tripolitania.

## Acknowledgments

The study at Qarahbulli was made with the help and cooperation of the Nazir of Agriculture of Tripolitania, other Provincial and local government officials, and farmers. The work was undertaken as part of the joint program of the Government of Libya and the United States Agency for International Development Mission to Libya (USAID/L). Most of the field work was done by trained Libyan technicians under the guidance of U.S. ground-water advisors.

## Geography

The Qarahbulli area lies within the physiographic unit known as the Gefara, which is a coastal plain sloping gently northward from the escarpment of Jabal Nafūsah to the Mediterranean Sea. The Gefara, which is relatively flat land interspersed with sand dunes, extends along the coast from southern Tunisia eastward to Al Khums (Homs) where it pinches out between the sea and the Jabal Nafūsah. A chain of oases extends along the coast from Zuwarah to Al Khums in a narrow belt about 5 to 10 km wide. These oases lie between fossil dunes along the present coast and an active sand dune belt, several kilometers wide, that begins about 5 to 10 km south of the coastline. The Jabal Nafūsah forms the southern boundary of the Gefara. The Jabal, an erosional scarp which rises some 600 m (meters) above sea level and some 400 m above the inland edge of the Gefara, consists principally of interbedded limestone, sandstone, and gypsum.

Along the coast of the Qarahbulli area is a belt chain of active dunes about 2 to 6 km wide that rises about 30 to 45 m above sea level. South of the coastal dunes is a belt about 5 km wide of relatively flat land much of which is under cultivation. South of the western part of this belt is another area of sand dunes. The Qarahbulli area is traversed by six ephemeral streams which rise on the slopes of the Jabal and drain north to the sea. These streams carry runoff only in response to heavy rains - generally during the winter months.

## Climate

The climate of the Qarahbulli area is characterized by low precipitation, high evaporation, and a wide range in daily and annual temperature. The average annual rainfall at Qasr al Qarahbulli for the period of record, from 1929 to 1939 and 1950 to 1961, is 311.3 mm (millimeters) (table 1). During these years the measured annual rainfall ranged from 171.4 mm in 1958 to 470.6 mm in 1932. The period of record, however, is too short to evaluate any long-term trends of cyclic effects that may be present.

Rainfall in the Qarahbulli area, as in most of coastal Tripolitania, is seasonal with the maximum precipitation in the winter months and little or no rain during the summer. Monthly averages, which range from 83 mm in December to 0.0 mm in July, tend to give a false impression of the temporal distribution, as the actual rainfall is quite erratic. For example, recorded rainfall for December has ranged from 5.0 mm in 1927 to 224.0 mm in 1960.

The Qarahbulli area lies within the limited farming zone described by J. H. Stewart (1960, p. 30) (fig. 3). Crops with low moisture require-

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Figure 3.--Map of northern Tripolitania showing average annual rainfall, in millimeters.

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ments such as barley, wheat, oats, grapes, olives, and melons can be successfully grown in the area with little or no supplemental irrigation during most years. During the period of record, the annual rainfall was below 200 mm for only 2 years and was above 250 mm for 20 of 27 years (table 1) indicating that the area can support limited dry-land farming.

Table 1.--Rainfall at Qasr al Qarahbulli, 1926-40 and 1950-61, in millimeters.

| Year | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1926 | 60.4 | 60.0 | 40.9 | 21.0 | 11.3 | 1.0 | 0.0 | 0.0 | (10.0) | (32.5) | 11.0 | 84.0 | 332.1 |
| 1927 | 92.0 | 54.0 | 28.0 | 2.0 | 8.0 | 0.0 | 0.0 | 0.0 | 11.3 | 9.0 | 0.0 | 5.0 | 209.3 |
| 1928 | 118.0 | 92.5 | (21.6) | (14.8) | 3.0 | 0.0 | 0.0 | 0.0 | (10.0) | 0.0 | 21.0 | 143.0 | 423.9 |
| 1929 | 113.5 | 74.7 | 33.8 | 0.0 | 1.0 | 24.0 | 0.0 | 0.0 | 22.7 | 5.5 | 23.1 | 39.1 | 337.4 |
| 1930 | 26.5 | 47.1 | 0.0 | 12.6 | 1.2 | 0.4 | 0.0 | 0.0 | 0.6 | 33.3 | 32.3 | 32.7 | 186.7 |
| 1931 | 68.6 | 51.0 | 2.3 | 0.5 | 14.0 | 0.0 | 0.0 | 0.0 | 33.1 | 8.3 | 3.6 | 94.1 | 275.5 |
| 1932 | 206.7 | 35.0 | 22.2 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 38.5 | 67.8 | 65.5 | 33.9 | 470.6 |
| 1933 | 30.8 | 36.0 | 120.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 24.7 | 114.2 | 326.1 |
| 1934 | 159.1 | 26.7 | 10.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 27.0 | 108.7 | 16.6 | 52.7 | 401.0 |
| 1935 | 125.7 | 18.7 | 9.3 | 2.3 | 0.0 | 0.0 | 0.0 | 0.2 | 9.8 | 7.0 | 24.0 | 21.0 | 218.0 |
| 1936 | 19.0 | 10.8 | 4.9 | 36.9 | 6.4 | 1.7 | 0.0 | 0.4 | 0.0 | 93.5 | 92.2 | 122.1 | 387.9 |
| 1937 | 25.0 | 39.3 | 6.2 | 16.4 | 0.2 | 0.0 | 0.0 | 0.0 | 2.6 | 108.9 | 11.4 | 19.4 | 229.4 |
| 1938 | 89.7 | 131.3 | 44.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.5 | 34.3 | 127.1 | 437.1 |
| 1939 | (72.9) | (40.3) | 22.8 | 8.7 | 0.5 | 0.0 | 0.0 | 0.0 | 1.6 | (32.5) | 23.4 | 32.3 | 235.0 |
| 1940 | 47.7 | 0.0 | 1.6 | 12.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.5 | 8.7 | 187.9 | 269.5 |
| | | | | | | | | | | | | | |
| 1950 | 110.0 | 73.3 | 57.4 | 3.0 | 25.8 | 0.0 | 0.0 | 0.2 | 0.0 | 36.0 | 37.5 | 47.5 | 390.7 |
| 1951 | 82.2 | 14.8 | 21.1 | 0.0 | 2.5 | 0.0 | 0.0 | 0.0 | 20.5 | 37.9 | 61.8 | 88.4 | 329.2 |
| 1952 | 54.8 | 80.4 | 0.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 61.5 | 95.6 | 306.3 |
| 1953 | 96.2 | 10.5 | 14.2 | 0.6 | 14.2 | 0.0 | 0.0 | 1.5 | 0.0 | 22.5 | 119.8 | 19.5 | 299.0 |
| 1954 | 23.2 | 20.9 | 7.8 | 10.3 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 25.8 | 16.6 | 169.5 | 274.6 |
| 1955 | 4.6 | 26.5 | 0.0 | 86.2 | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 35.7 | 33.0 | 107.0 | 295.7 |
| 1956 | 16.5 | 34.5 | 33.8 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 6.9 | 17.0 | 5.6 | 93.9 | 208.7 |
| 1957 | 116.7 | 0.0 | 5.2 | 46.5 | 16.2 | 6.5 | 0.0 | 0.0 | 0.5 | 79.2 | 85.3 | 89.9 | 446.0 |
| 1958 | 29.7 | 7.2 | 14.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 26.0 | 51.0 | 37.0 | 171.4 |
| 1959 | 50.0 | 53.0 | 3.0 | 2.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.5 | 54.2 | 35.4 | 119.0 | 318.1 |
| 1960 | 19.0 | 10.5 | 11.5 | 44.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | 0.0 | 20.5 | 224.0 | 339.5 |
| 1961 | 110.8 | 40.5 | 47.5 | 24.0 | 8.0 | 1.5 | 0.0 | 0.0 | 0.0 | 14.0 | 0.5 | 41.0 | 287.8 |
| Average | 72.9 | 40.4 | 21.6 | 13.3 | 4.2 | 1.3 | 0.0 | 0.1 | 7.9 | 32.5 | 34.1 | 83.0 | 311.3 |

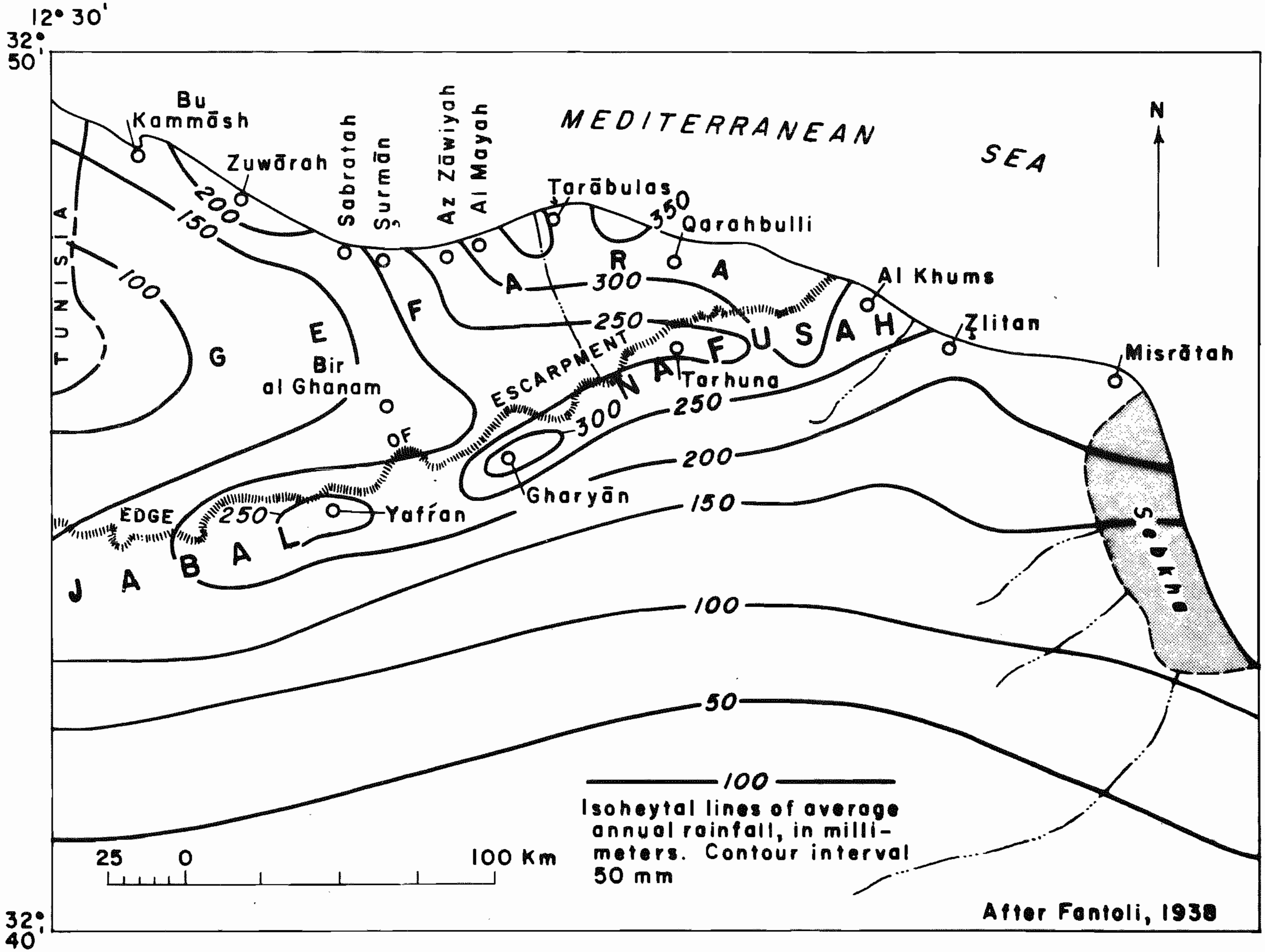


Figure 3.--Map of northern Tripolitania showing average annual rainfall, in millimeters.

The frequency as well as the amount and distribution of rains is a very important factor in the pattern of cultivation in this area. Optimum conditions for growth of barley, other cereals and vegetables require a sequence of moderate rains beginning in late October and extending through March with few extended dry periods. Variations from these conditions, of course, greatly affect the yield of crops.

## Stratigraphy

Rocks exposed in northern Tripolitania range in age from Triassic to Recent (table 2), and at least 4 drilled wells in the Qarahbulli area have penetrated formations older than the Miocene. The rocks of the region consist of a sequence of sedimentary formations that dip gently and thicken gradually toward the sea from near the foot of the Jabal Nafūsah; thus they are not only thicker toward the sea but also lie at greater depth than inland. The process of deposition did not occur evenly, as some formations at places were either eroded away prior to burial by younger beds or were not deposited. Post-depositional faulting and folding also affects some of the beds.

### Mesozoic rocks

The oldest formation exposed in northern Tripolitania is the Ras Hamia Formation of Middle Triassic age (Burollet, 1960, p. 44). The type section exposed near Al Azīzīyah consists of some 74 m of dark-red, fine-grained, micaceous sandstone, red and green silty clay and claystone, and vari-colored siltstone. Only the uppermost part of the formation is exposed at the type locality and the total thickness may be several hundred meters.

Table 2.--Generalized section of geologic formations for northwestern Tripolitania.

(After Christie, 1955)

| System | Series | Group or Formation | Thickness (meters) | Lithologic Description | Water-bearing Character |
|---|---|---|---|---|---|
| Quaternary | Recent | | | Loess, wind-blown sand | |
| Quaternary | Pleistocene | Garagaresc calcarenite | 0-30+ | Loosely cemented coquinoid calcareous sandstone | Yields some potable water locally but quality soon deteriorates with use owing to proximity to sea |
| Quaternary | Pleistocene | Gefarico silt with intercalations of marine deposits | 50+ | Calcrete, silty sand, loosely cemented sandstone, limestone and clay | Upper strata yield small to moderate amounts of water wells. Lower strata yield moderate to large amounts. Principal aquifers of the area |
| | | ? | ? | | |
| Tertiary | Pliocene | Unconformity | ? | May be present but not identified in subsurface | |
| Tertiary | Miocene | | 560± | Marine limestone, sandstone, and clay found in subsurface in northern part of Gefara | Middle sandstone strata yield moderately saline water, but little known about quality and quantity. Basal sandstone strata yield large quantities of brackish water |
| Cretaceous | Upper (Cenomanian to Turonian) | Gasr Tigrinna Formation | 87 | Limestone, dolomite, marl, sandstone, clay and conglomerate that are exposed on the front of Jabal Nafusah and may also underlie the Miocene near the coast | Yields small to large amounts of potable water. Many springs flow from the Ain Tobi and Chicla Formations |
| | | Garian dolomite | 55 | | |
| | | Nefusa Group<br>Jefren Marl<br>Ain Tobi Limestone | 79 | | |
| | Lower (Wealden) | Chicla Formation | 0-65 | | |
| Jurassic | | Bir el Ghnem Group | 100± | Gypsum and limestone with beds of clay and sandstone. Not identified in the subsurface near the coast | Not considered a source of potable water |
| | | ? | | | |
| Jurassic / Triassic | Upper (Kueper) | Bu Sceba Formation | 165± | Sandstone, conglomerate, clay, and some gypsum | Yields moderate amounts of slightly saline water to wells. Supplies water for irrigation near Bir al Ghanam |
| Triassic | Middle (Muschelkalk) | Azizia Limestone | 110 | Limestone and chert, exposed near Azizia | Not considered a source of water |
| | | Ràs Hamia Formation | 800± | Micaceous sandstone, silty clay, claystone | Reported to yield large amounts of water for irrigation near Al Aziziyah |

The Azizia Limestone overlies the Ras Hamia Formation (Christie, 1955, p. 4-6). In the type section at Al Azīzīyah 61 m of light to dark-grey compact fossiliferous limestone with bands and nodules of chert is exposed. The Azizia is used as road metal and as an ornamental building stone.

The Bu Sceba Formation (Christie, 1955, p. 15-16; Burollet, 1960, p. 10) has been described as Late Triassic to Early Jurassic in age. The formation comprises about 165 m of red to brown sandstone, pebble conglomerate, white sandstone, red and green clay, and minor amounts of gypsum.

The Bi'r el Ghnem Group of Jurassic age consists of about 100 meters of gypsum and limestone with thin beds of clay and sandstone.

Five stratigraphic units of Cretaceous age have been identified (Christie, 1955, p. 17-20) from their exposures in the Jabal Nafūsah escarpment. They consist of limestone, dolomite, marl, clay, sandstone and conglomerate.

Rocks of pre-Miocene age have been reached by 4 drilled wells in the report area. The rocks encountered include limestone with some sandstone, clay shale, marl and conglomerate. Although a positive age determination of these rocks is not available, a tentative Cretaceous age is assigned.

## Tertiary rocks

Miocene rocks consisting chiefly of limestone, clay, marl, quartz sand and sandstone overlie the Mesozoic rocks. The Miocene attains a thickness of approximately 560 m in the coastal Gefara according to Desio (1940) and more than 350 m in the Qarahbulli area. The Miocene strata generally dip northerly at about 15 m per kilometer in most of the Gefara, however, the dip appears to be somewhat greater in the Qarahbulli area (fig. 4). The Miocene strata appear to thicken rapidly downdip, or

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Figure 4.--Map showing the approximate position, with respect to sea level of the base of the Miocene series.

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to the north as shown in figure 5.

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Figure 5.--Geologic cross-sections through the Qarahbulli area.

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## Quaternary deposits

Quaternary deposits most of which are loosely consolidated form the surface rocks of the Qarahbulli area and adjacent parts of the Gefara. These deposits are of eolian and marine origin and range in thickness from zero at the Miocene outcrop to more than 40 m near the coast.

The lower part of the deposits consists of loosely cemented silty sand, some limestone, and clay. The upper part consists of unconsolidated eolian sand, loess, calcrete and some loosely cemented sand.

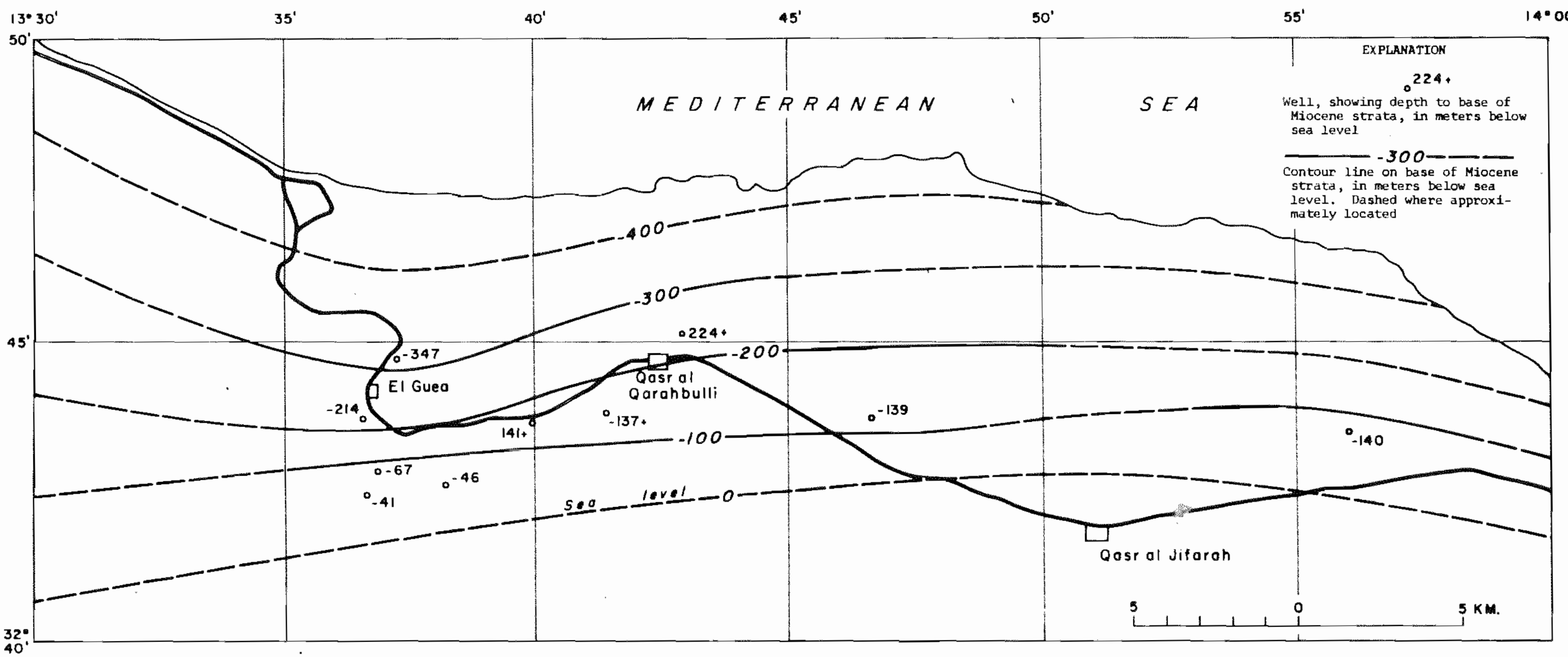


Figure 4.--Map showing the approximate position, with respect to sea level, of the base of the Miocene series.

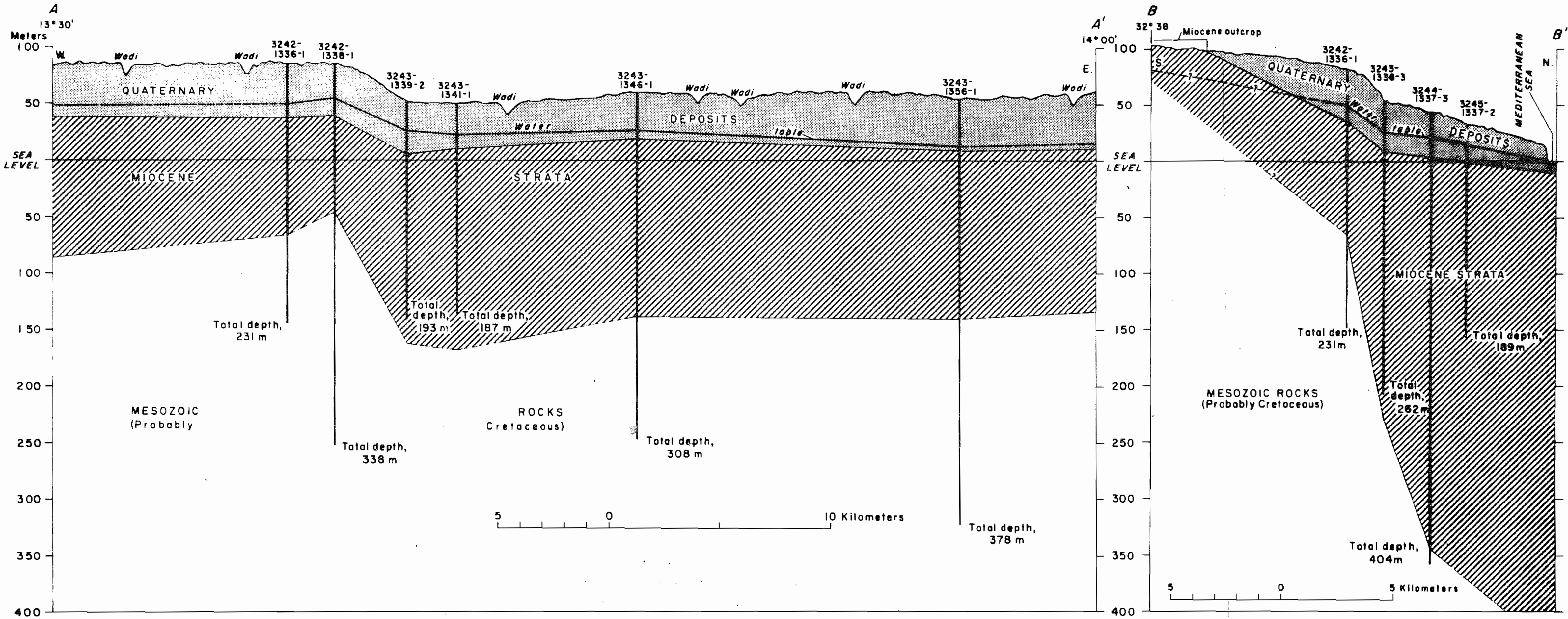


Figure 5.--Geologic cross-sections through the Qarahbulli area.

## Ground water

### Source and occurrence

The source of most fresh water on the earth is precipitation. The process of evaporation, condensation, and precipitation known as the hydrologic cycle, (fig. 6) is continuous and has no beginning or end.

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Figure 6.--The hydrologic cycle.

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Water evaporated from the land and water surfaces, is borne as vapor into the atmosphere where it condenses and falls back to the earth as rain. Some of the precipitation sinks into the ground, some runs off into streams, and some is evaporated back into the atmosphere. The water that sinks into the ground flows underground and reappears at the surface as springs or enters the ocean directly. The water in the streams flows to the ocean where it is again evaporated into the atmosphere thus completing the hydrologic cycle.

Water, which occurs naturally as rain, falls on the surface of the ground and percolates downward through the pore spaces of the soil and forms the zone of saturation. The upper surface of the zone of saturation is known as the water table. The water in the zone of saturation, sometimes referred to as "phreatic water", moves by gravity flow towards areas of discharge.

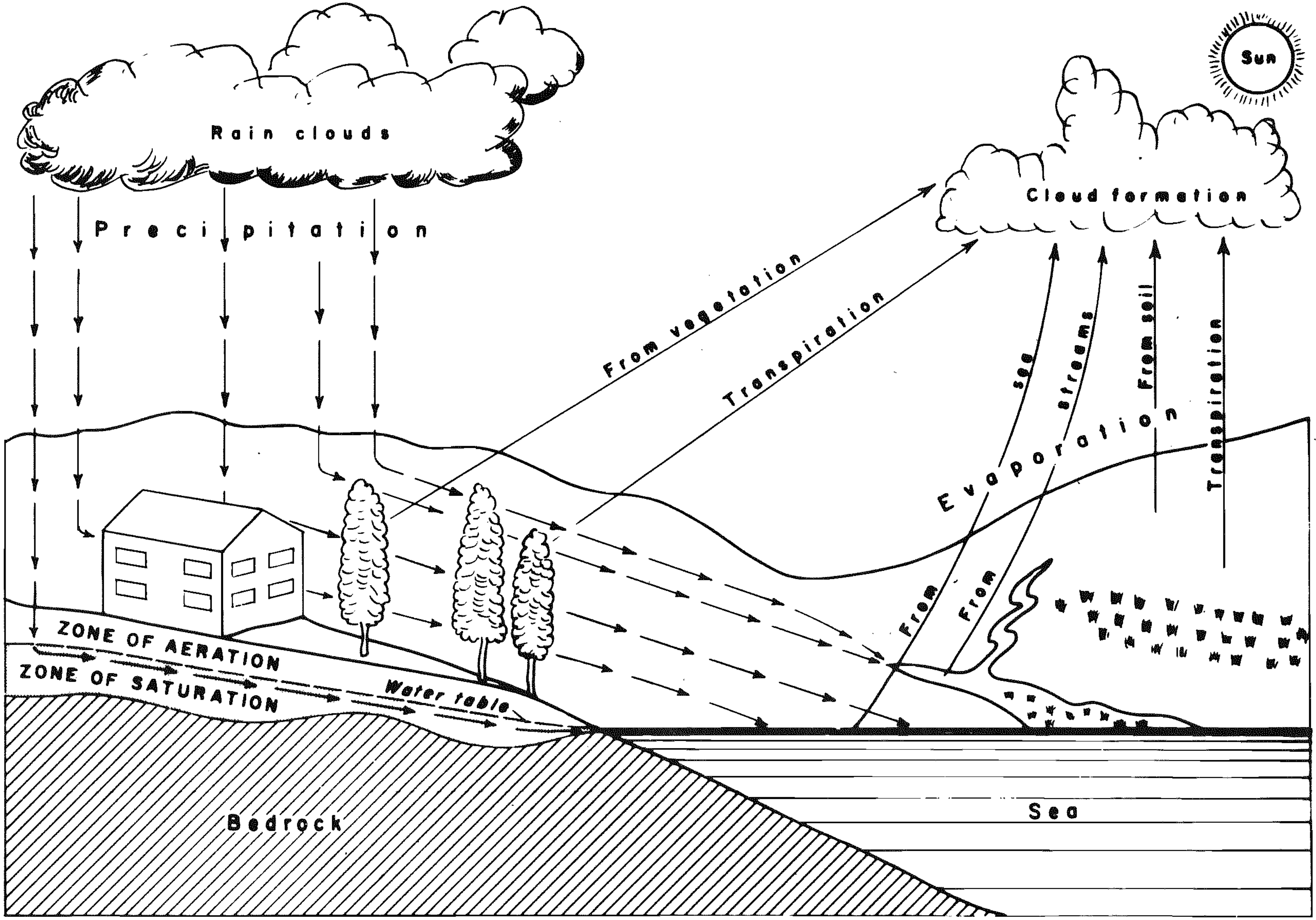


Figure 6.--The hydrologic cycle.

Ground water also occurs as confined or artesian water. A gross over-simplification of the origin of an artesian aquifer is described below. As water moves through a formation by gravity flow the water-bearing strata commonly pass beneath overlying impermeable beds which restrict vertical flow. If the bed beneath the water-bearing formation is also impermeable, the water-bearing formation is said to be confined or artesian. As the water continues to flow through this confined formation it acquires a hydrostatic pressure proportional to the vertical distance between the elevation of the point of confinement and the top of the confined bed at any point.

Ground water is stored in the earth in the pore spaces of the different types of rocks in which it is found. All granular material in the earth contains openings between the grains or particles, but the openings differ in number, size, and shape. In materials such as clay and silt, the open spaces are very small, and therefore, do not readily yield water to wells. Sand, gravel, and fractured massive rocks may have large interconnected spaces through which water can flow freely. The size and amount of the voids or open spaces of the water-bearing formation affect the ability of the formation to transmit and store water.

## Water-bearing formations

### Mesozoic rocks

The oldest water-bearing formations known in northern Tripolitania are the Ras Hamia, Azizia and Bu Sceba of Triassic to Jurassic age. Usable water in these aquifers is tapped at depths ranging from 100 to 325 m near Bi'r al Ghanam and Al Aziziyah. For example, a test hole drilled 2 km south of Al Azīzīyah encountered a very permeable aquifer in the Ras Hamia at a depth of 324 m. A few wells of low yield also tap water-bearing zones in the Azizia near the type locality. Permeable beds in the Bu Sceba yield water rather freely to wells at Bi'r al Ghanam. Potable water is also obtained from springs issuing from the Cretaceous rocks, notably the Ain Tobi Limestone, of the Jabal Nafūsah to the south of the report area. Presumably, all these formations underlie the Qarahbulli area but probably at considerable depth. The water contained in these formations probably would be salty or brackish beneath the report area. Water in the rocks of presumed Cretaceous age and immediately beneath the Miocene of the Qarahbulli may be of chemical quality suitable for some purposes.

## Tertiary rocks

Artesian aquifers in the Miocene supply a large part of the water used for irrigation in the area near El Guea. Artesian water has been reported at 5 different horizons in wells penetrating Miocene rocks at depths ranging from less than 100 m to more than 300 m. In well number 3244-1337-3 Miocene aquifers were encountered at 90 m, 182 m, 212 m, 236 m, and 340 m. When the well was first drilled the water level was reported to rise 12 m above land surface. These artesian aquifers have been tapped by several wells in this general area, however, all the wells do not flow at the land surface, especially those tapping only the aquifers at intermediate depth.

Flowing artesian water from the basal Miocene has been encountered in many wells east of Tripoli, however, the water is both hot and highly mineralized and generally unsatisfactory for irrigation. During drilling of these wells, aquifers in the middle Miocene were cased off or ignored as interest at the time of drilling was solely in artesian flow.

## Quaternary deposits

Quaternary deposits overlying the Miocene constitute an important aquifer in the area around Qasr al Qarahbulli. The Quaternary deposits furnish most of the water used for domestic and public supply and also furnish water for irrigation in many of the Cabilas. The aquifer is considered to be unconfined to semi-artesian for it is hydraulically continuous over a large area but locally vertical movement of water may be impeded by less permeable beds. Consequently, when the lower beds are penetrated by a well, the water will rise in the well to the level of the water table.

As in other parts of the Gefara the Quaternary deposits in the Qarahbulli area may be divided into an upper zone of loosely consolidated sand which yields small amounts of water to dug wells and a more permeable lower zone of loosely cemented sandstone, limestone and clay which furnish moderate quantities of water to wells for irrigation. The depth of wells penetrating the Quaternary aquifer ranges from about 20 to 40 m.

## Hydraulic characteristics

Under natural conditions and over a long period of time, the hydraulic system of a water-bearing formation is essentially in balance, that is the natural discharge is equal to the recharge. When this natural balance is upset by a withdrawal of water, as from an irrigation well, an adjustment is made which results in a decline in the water level. Water in transit between the area of recharge and the discharge area is said to be in storage. When water is withdrawn from a well that penetrates an aquifer, the direction of flow of the water in the vicinity of the well is changed. The withdrawal causes a lowering of the water level around the well in the form of an inverted cone, the well being at the center. As the cone expands and deepens, water flows to the well from all directions (Fig. 7). The

Figure 7.--Diagram showing movement of ground water around a cone of depression of a pumped well near sea level.

rate of decline of the water level and the outward spread of the cone depend on the hydraulic characteristics of the formation as well as the rate of pumping. The magnitude of the decline in water level varies directly as the rate of withdrawal of water, and increases with the logarithm of time that has elapsed since withdrawals began.

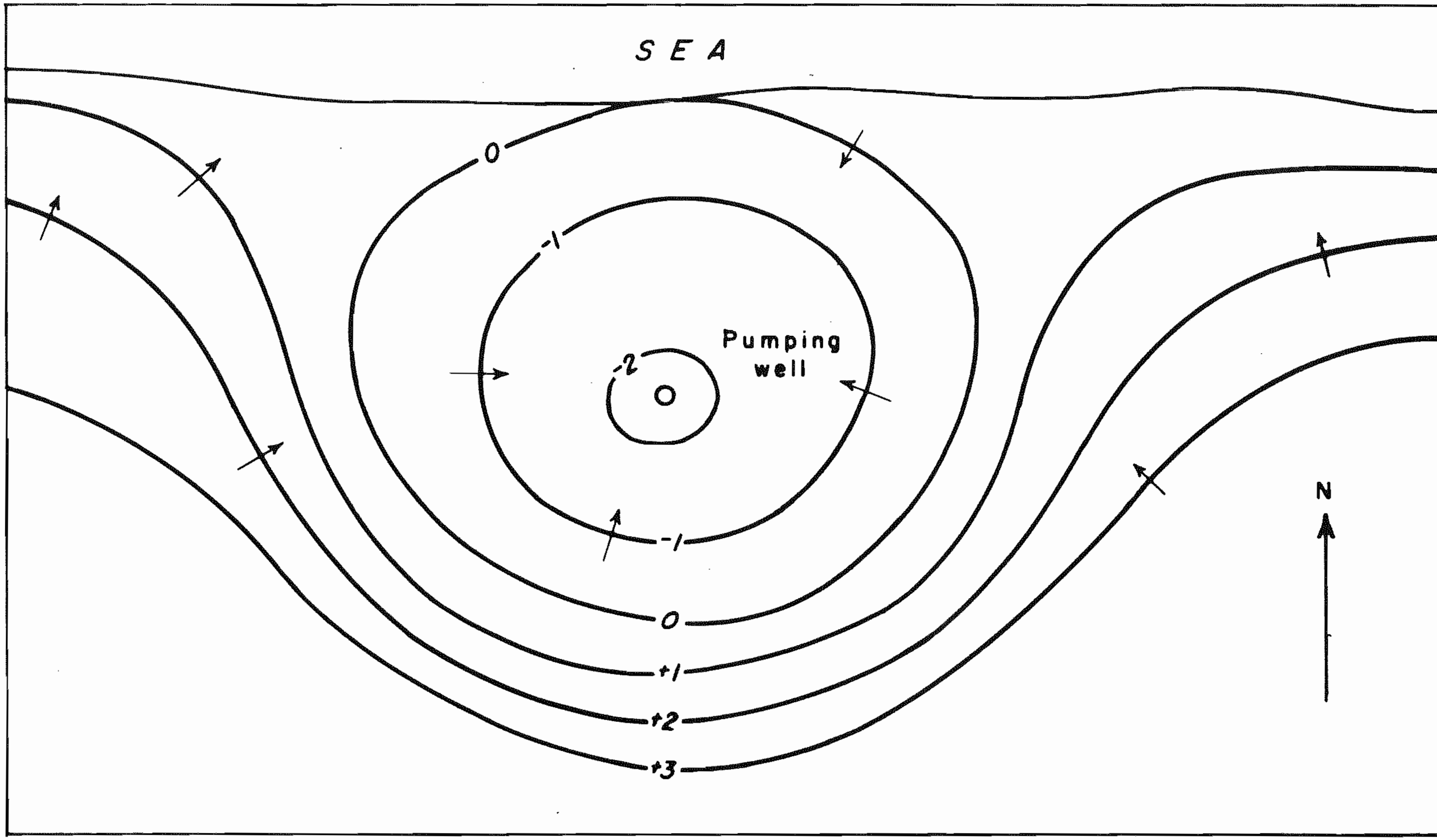


Figure 7.--Diagram showing movement of ground-water around a cone of depression of a pumped well near sea level.

Two of the hydraulic characteristics of water-bearing formations which affect the rate of decline of water levels in wells are the ability of the formation to transmit water, and the capacity of the formation to yield water from storage. These are known as the coefficient of transmissibility and the coefficient of storage. The coefficient of transmissibility is defined as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer one foot wide, extending the full saturated thickness of the aquifer under a hydraulic gradient of one foot drop in head in one foot of flow distance. The coefficient of storage is defined as the volume of water an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

In January 1960, during the period of minimum ground-water withdrawals for irrigation, pumping tests were conducted on the Miocene aquifers at El Guea (table 3) by W. T. Stuart of the U.S. Geological Survey, to determine the coefficients of transmissibility and storage. A pumping test was made by changing the rate of withdrawal from a well and observing the recovery or drawdown of the water levels in other wells within the cone of depression. Three tests were conducted using wells 3243-1336-3, 3243-1339-2, and 3244-1337-2 for withdrawals and well 3243-1336-4, equipped with water-stage recorder, as the observation well. The water-bearing formations demonstrated a high capacity to transmit water freely to wells. The coefficient of transmissibility ranged from 150,000 to 430,000 gallons per day per foot (78 to 222 cubic meters per hour per meter.) The coefficient of storage of 0.000003 is low, and is in the range of elastic deformation of the formation caused by ground-water withdrawals.

Table 3.--Data on test of water-bearing formations in Province of Tripolitania, Libya (Stuart, W. T., 1960, p. 9).

| Area | Date | Water withdrawn from well number | Observation well number | Distance between withdrawal well and observation well (meters) | Rate of flow (cubic meters per hr.) | Transmissibility | | Storage coefficient | Boundary conditions (B=Barrier) (number is the distance from observation well, in meters) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $\frac{M^3/hr}{m}$ | gpd/ft | | |
| El. Guea | 1-17-60 | 1375-59 | 1375-48 | 5,950 | 204 | 78 | 150,000 | 0.00003 | $B_2$=4,300 SE |
| | 1-22-60 | 1375-102 | 1375-48 | 2,590 | 91 | 103 | 200,000 | .00003 | $B_1$=1,200 W<br>$B_2$=7,600 S<br>$B_3$=7,600 N |
| | 1-24-60 | 1375-47 | 1375-48 | 700 | 284 | 222 | 430,000 | .00003 | |
| Bianchi | 1-27-60 | Bianchi 120 | -- | 40.3 | 40.2 | 35 | 68,000 | .0007<br>.0016 | B=324 |
| Gasr Ben Gascir | 1-26-60 | 1374-87 | 1374-86 | 5.5 | 34.1 | 88 | 170,000 | -- | none |
| | | 1374-87 | 1374-88 | 71.7 | 34.1 | 228 | 440,000 | .0015 | do |
| | 1-30-60 | 1374-87 | 1374-86 | 5.5 | 36.0 | 72 | 140,000 | -- | do |
| | | 1374-87 | 1374-88 | 71.7 | 36.0 | 233 | 450,000 | .0015 | do |
| | | 1374-87 | 1374-26 | 505. | 36.0 | 398 | 770,000 | .036 | do |

The tests established the existence of ground-water barriers to the north, west, and south of the observation well, 3243-1336-4. The test using well 3243-1336-3 for discharge located 3 barriers, whereas using 3243-1339-3 for discharge only one boundary to the southeast, was encountered. The period of discharge of well 3243-1339-2 may not have been of sufficient duration to allow the cone of depression to intercept the other two barriers encountered with well 3243-1336-3.

The hydraulic barrier to the south may be interpreted as the outcrop of the basal Miocene sand (Vorhis, personal communication) (fig. 2) whereas, the other two barriers may be attributed to a lensing effect of the water-bearing formation or possible faults or both. Lack of knowledge of the geology of the area precludes analyses of the nature of these barriers.

Tests of the Quaternary aquifer were not conducted in the Qarahbulli area. The hydraulic properties of the aquifer however, are believed to be similar to that tested at Gasr ben Gashir and Bianchi (Azzahra) (table 3); therefore, the hydraulic coefficients should be of the same magnitude.

## Recharge and discharge

Recharge to the aquifers in the Qarahbulli area is from direct infiltration of water from precipitation and from runoff in ephemeral streams in the region. Much of the recharge comes from local rainfall that percolates down into the ground-water reservoir, however, it is difficult to predict how much recharge will occur in any one year. During drought years the recharge may be small, whereas, during periods of heavy rainfall a high percent of precipitation may enter the ground-water reservoir as recharge. Much of the recharge also comes from the runoff of ephemeral streams draining seaward from the Jabal Nafūsah. The water flows northward from the steep wadis of the Jabal front and disappears into the ground along the wadi channels. Generally, only exceptionally high runoff originating in the Jabal reaches the sea. Information is not available to evaluate the rate of recharge that occurs in relation to rainfall. Correlation of rainfall and recharge would be difficult to determine because water is being withdrawn continuously for irrigation causing an overall decline in the water level that masks the effects of ground-water fluctuations due to normal causes. Detailed recharge studies therefore, were beyond the scope of this report.

Ground-water discharge occurs both by natural and artificial means. Water is discharged naturally from a ground-water reservoir by submarine outflow, spring flow, and by evapotranspiration. Submarine outflow below sea level probably forms a large part of the natural discharge of the Qarahbulli area. Discharge by evaporation may also be substantial where the water table is near the surface.

The total annual ground-water discharge through wells for irrigation and domestic supply in the Qarahbulli area was computed by estimation methods. The data were supplied in part by the owners and the rest was acquired from other sources. To obtain the information required an inventory of water wells was conducted in the Qarahbulli area in 1962. The inventory was not complete, however, but most of the deeper wells of substantial discharge were visited and described. Table 4 lists the reported yield, crops and number of hectares irrigated. Information received from the Mudir of the Qarahbulli District listed 203 drilled wells, exclusive of Italian farms. Most of the wells have been drilled since 1959 and were bored to deepen or replace old dalu-type dug wells. The wells are equipped with small centrifugal pumps and used to irrigate small farm plots of 2 to 4 hectares.

Irrigation requirements given by Casadio (Lewis, 1954, p. 55) and by Fred Tileston (1961, written communication) were used to estimate the annual withdrawal from those wells for which the crops and hectares irrigated were available.

Using the computed consumption from the inventoried wells plus an estimate for the additional reported drilled wells, a total consumption of 7,000,000 cubic meters per year ($m^3/yr$) was derived for the Quaternary aquifer. The annual withdrawal from the Miocene aquifers was computed to be about 2,000,000 $m^3/yr$ making the total annual discharge some 9,000,000 $m^3/yr$.

## Well yields

Individual wells tapping the Quaternary aquifer in the Qarahbulli area have yields ranging from 1 cubic meter per hour ($m^3$/hr) to 60 $m^3$/hr (250 gpm). There are about 250 wells with yields ranging from 15 to 60 $m^3$/hr (67 to 250 gpm). Most of these wells however, do not fully utilize their installed pumping capacity for they are pumped only for short periods of time to irrigate small Arab gardens. There are also about 600 dalu-type (animal powered) wells that individually yield about 1 $m^3$/hr.

There are about 20 wells of high yield, most of which are located near El Guea, that penetrate Miocene artesian aquifers. Some of the wells reportedly flowed up to 250 $m^3$/hr when first drilled, however, in recent years the yields of many of these have declined owing to a loss in hydrostatic pressure or to faulty well construction or both. Pumps have also been installed on some of the wells where the artesian pressure was not great enough to produce sufficient flow for irrigation.

Most of the drilled wells in this area use centrifugal pumps set in an "avampozzo", which is a dry well dug to a level just above the water table. A minimum distance must be maintained between the pump and the dynamic water level (pumping level) as the maximum effective lift of a centrifugal pump is about 8 meters (28 feet). The amount of water that a well can pump is controlled somewhat by the specific capacity of the well (the yield of the well per unit of drawdown). If the specific capacity of the well decreases or is low, the rate of discharge cannot necessarily be augmented by increasing the pumping rate or size of the pump.

The yields of many of the wells in the Qarahbulli area could be increased if they were developed properly by modern water well-construction methods. Most of the drilled wells are not properly cased and screened and rarely properly developed. Few of the wells completely penetrate the water-bearing formation. Commonly only the upper portion of the well is cased leaving the lower part of the well open and subject to sanding. This practice is especially common in the farming development north of Qasr al Qarahbulli. For example, well 3245-1343-1, which had a reported yield of 40 $m^3$/hr when drilled and deepened in 1959, now (1962) becomes dry after 1/2 hour of pumping. Several meters of casing were placed in the uppermost section of the well but the remainder of the hole was left open or uncased. The well has probably sanded in or caved below the casing, thus blocking or restricting the flow of water into the well.

## Present and potential development

Agricultural development has been restricted largely to the relatively flat area south of the belt of coastal sand dunes and along the trace of the highway. The principal farming areas are centered near El Guea and Qasr al Qarahbulli. The Italians and later USOM/Libya drilled several wells in the Miocene and obtained flowing artesian water suitable for irrigation. Most of these wells were drilled near El Guea and Qasr al Qarahbulli and are situated largely on the Government Experimental Farms and on local Italian farms near the highway. The yields obtained from the wells tapping the Miocene range from 60 $m^3$/hr to a reported 250 $m^3$/hr. Many of the wells still (1962) flow at the land surface, but pumps have been installed on some of the wells to increase yields and to compensate for loss of hydrostatic pressure. The water is used mostly to irrigate large-scale agricultural developments owned or operated by Italian farmers. Many modern farming and water-conservation methods such as row-type irrigation, sprinklers, lined canals, and aluminum pipe are used in the cultivation of oranges, peanuts (ground-nuts), grains, vegetables, and olives. Many small Arab farms have been developed along the edges of the larger holdings. The largest area of these small farms is near Qasr al Qarahbulli.

In the eastern part of the area near Qasr al Jifarah, where the highway approaches the Miocene outcrop irrigated farming appears to be at a minimum. East of Qasr al Jifarah much of the cultivated land along the highway is devoted to dry-land farming of the olives, grapes, and other crops of low-moisture requirement. In much of this area the Quaternary deposits are quite thin and cisterns are used to collect water. West of El Guea the land is predominantly sand dunes and little development has occurred.

The sand dune areas along the coast and east of El Guea hold some promise for future development. These sand areas are interspersed with numerous flat-lying tracts. With afforestation and other sand-dune stabilization methods much of this land could be put into cultivation if suitable water is available. These areas may not be conducive to large-scale intensive farming methods but could be developed for the small garden-type of farm which is so prevalent in Libya. One such flat-lying tract has been developed in the sand dune area west of El Guea near well 3247-1330-2. Another example is located north of Qasr al Jifarah near well 3245-1250-2 in Cabila Adul. These wells and the newly deepened wells near Qasr al Qarahbulli have been drilled by the Well Boring Section of the Nazarate of Agriculture with hand-operated churn drill rigs.

Wells penetrating Cretaceous (?) rocks encountered artesian water of unknown quality at depths of over 200 m (fig. 5). A description of these rocks is given in the drillers logs for wells 3243-1346-1 and 3243-1356-1 (table 5). If the water from these rocks is suitable for irrigation, they could represent a potential source for future development. The Cretaceous (?) rocks which are believed to underlie the area south of the present developed area, probably also rise closer to the surface as they approach the Jabal.

## Water levels

Water levels in wells are one of the most important indices used in evaluating the water supply of an area. Changes in water levels resulting from discharge of water are a measure of the overall effect of discharge upon the aquifer. If the static water level fails to return to its original level after cessation of extended pumping then this fact suggests that the water is being withdrawn faster than it is being replenished. During the period of minimum withdrawals, in the winter months, the water levels are generally at their highest level. It is during this time that static water levels for year to year comparison and evaluation are usually measured.

Using water-level measurements made in 1962 a map showing the depth to the water table was constructed (fig. 8). Both the land surface and

Figure 8.--Map showing depth to the water table in the Qarahbulli area, 1962.

the water table slope to the north toward the sea. The land surface rises to the south at a steeper slope than that of the water table and consequently, the depth to water, below land surface increases to the south as shown in figure 8.

The depth to water is of great importance to farmers using ground water for irrigation, for as the depth to water becomes greater the cost of lifting water to the surface increases. If the farmer uses a dalu he must pump water for a longer period or purchase a pump, or if a pump is already installed, he must use more power which will increase the cost of operation.

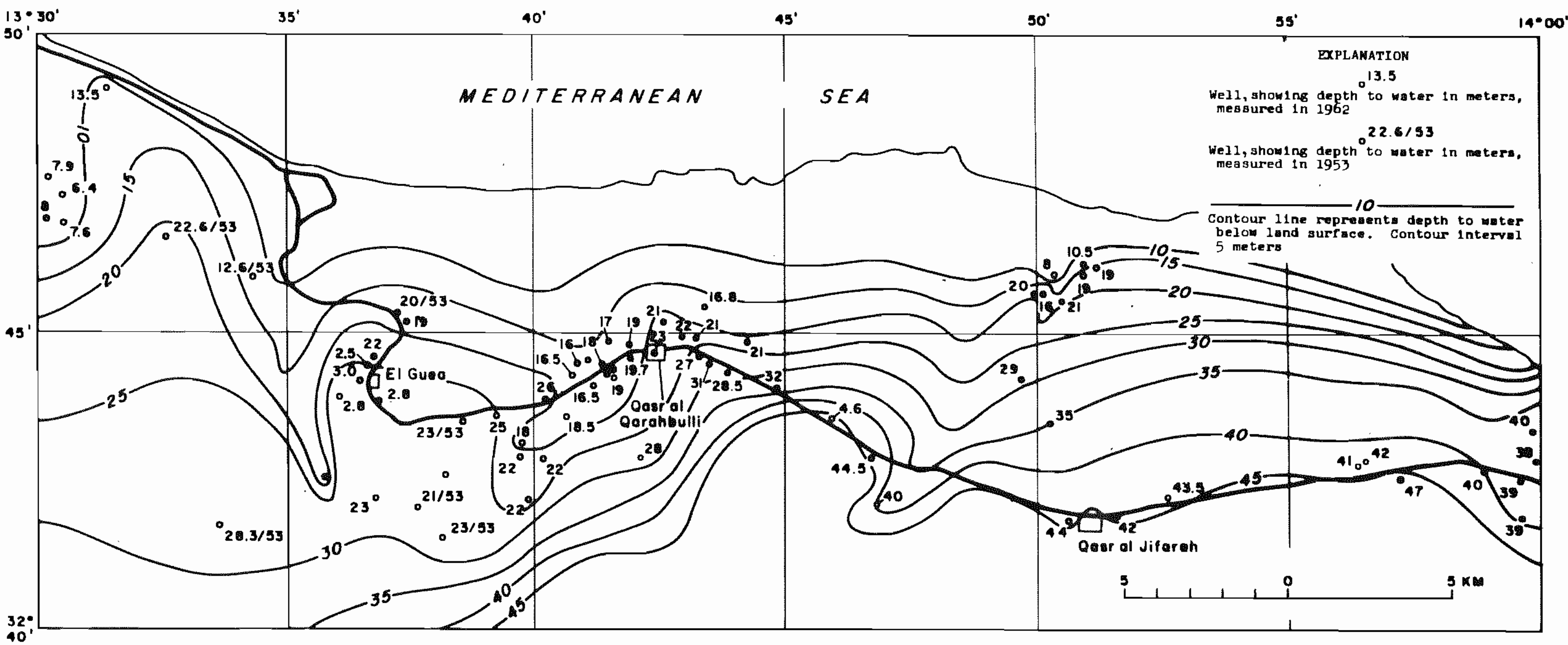


Figure 8.--Map showing the depth to water in the Qarahbulli area, 1962.

Very few water-level measurements are available for the Qarahbulli area prior to 1961-62. Water levels measured in wells near Qasr al Qarahbulli in the spring of 1961 and 1962 indicated that the decline of the water table is about 0.2 m per year, (fig. 9). Many of the wells east of

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Figure 9.--Map showing water level decline in the Qarahbulli area.

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Qasr al Jifarah show a decline in 1961-62 of about 0.5 m. These wells are drilled to depths of 60-70 meters and are believed to tap upper Miocene aquifers.

Many of the artesian wells in El Guea area still flow at the surface, but the hydrostatic pressure, or head has declined. A maximum head of 14 m above land surface was reported in well 3245-1337-2 when drilled in 1939. In 1960, prior to the pumping test by Stuart (1960), the maximum head in the well was reported to be 5 m. Well 3243-1341-1 had a reported head of 8 m above land surface when drilled in 1937, but in 1961 the water level was 0.70 m below land surface. These measurements indicate an average annual decline in head of about 0.4 m. The water level in well 3243-1336-4 was 8.2 m below land surface when drilled in 1956, but in 1959 it was 10.6 m. The decline of 2.3 m, which is about 0.6 m per year, indicates that the rate of decline may have accelerated in recent years. If this rate of decline continues, pumps will eventually have to be installed on all of the artesian wells in this area. Well 3243-1336-4 has a yield of 110 $m^3$/hr with a drawdown of 4.3 m after 24 hours pumping. If these conditions are true for the other artesian wells, then centrifugal pumps could be used to raise the water to the surface by setting the pump in an avampozzo near the static water level.

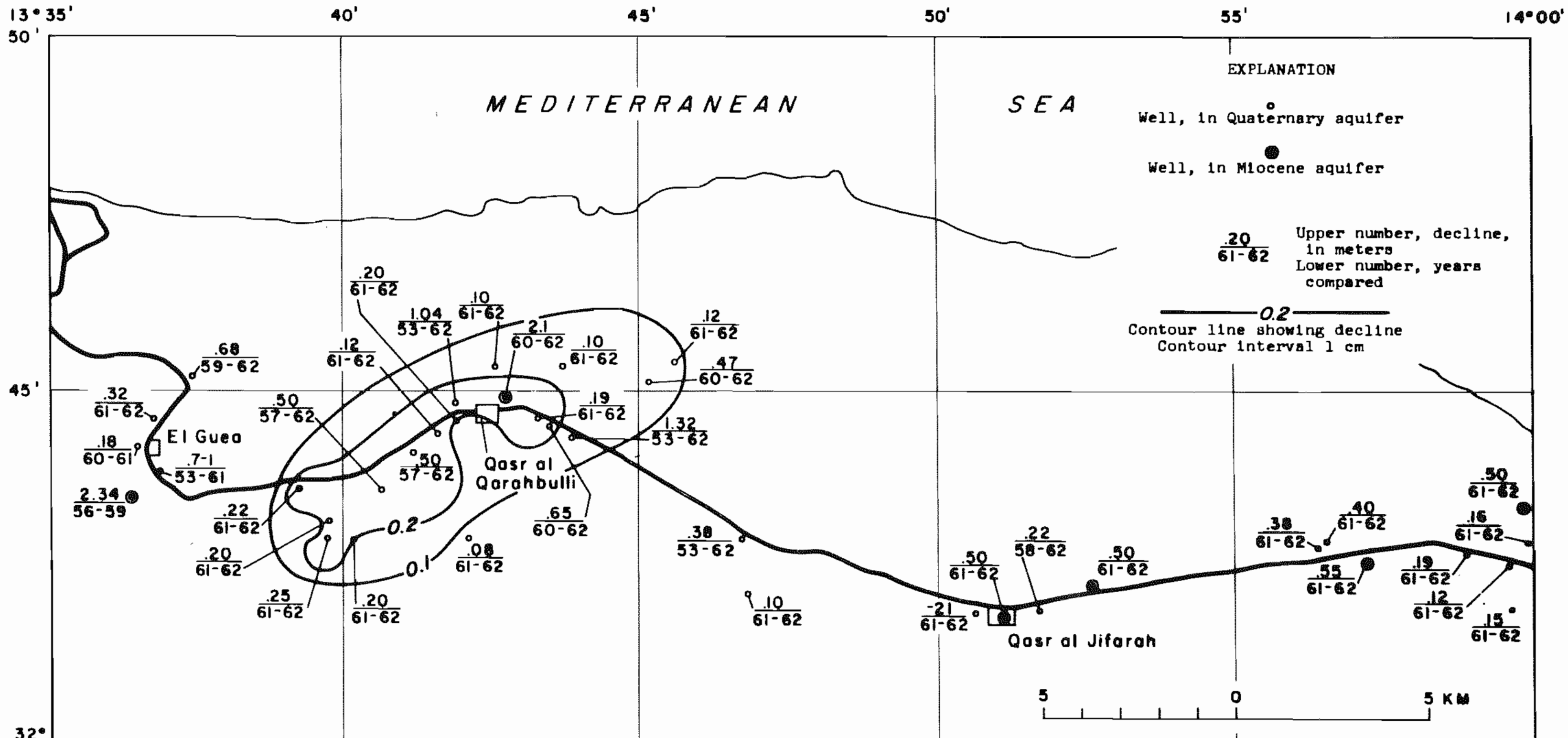


Figure 9.--Map showing water-level declines in the Qarahbulli area.

## Quality of water

### General features

All ground-water contains dissolved minerals but the content varies through a wide range. Water from some wells may contain as little as 200 parts per million (ppm) of dissolved solids, whereas water from other wells may contain as much as 20,000 ppm or more. Useful limits of water are difficult to determine for although waters containing large amounts of dissolved solids are not considered to be potable they may be useful for other purposes such as livestock or industry. As the mineral content increases, however, the usefulness of the water decreases markedly.

Quality of water determinations are generally expressed in concentrations of individual ions for those substances known to be dissociated in solution. Determinations commonly made in water analyses included cations, anions, and certain more general chemical and physical properties such as acidity (pH), hardness, specific conductance, and dissolved solids. The number of chemical determinations of an analysis is governed by the nature of the investigation.

Dissolved solids is a measure of the total quantity of matter carried in solution by the water. Dissolved solids have a direct relationship to the specific conductance (conductivity) of the water and can be easily estimated from the conductivity. Specific conductance, an electrical property, which is used as an index of the total salinity of the water, can be measured easily and accurately in the laboratory and in the field.

The cations ordinarily present in significant concentrations in ground-water are calcium, magnesium, sodium, and potassium. Calcium, magnesium and potassium are essential plant foods; however, although sodium is used by many plants it is not as essential as the other nutrients and may be toxic to some plants.

The more important anions in irrigation water include carbonate, bi-carbonate, sulfate, chloride and nitrate. Sulfate and nitrate are essential nutrients in reasonable concentrations. Chloride in high concentrations is toxic to many plants.

The precipitation of sodium carbonate, resulting from evaporation of irrigation waters containing high bicarbonate ion concentrations, forms a "black alkali" deposit which has a deleterious effect upon soil structures. This condition is not prevalent in the report area because the bicarbonate ion concentrations of the waters are relatively low and the soil has good drainage.

Ground water in the area of study is used principally for domestic supply, irrigation, and livestock. The quality of water for these purposes can vary through a wide range. The preferred upper limits in parts per million for total dissolved solids and other common chemical constituents in drinking water as prescribed by the United States Public Health Service (1961), is shown in the table below.

| | ppm | | ppm |
|---|---|---|---|
| Chloride | 250 | Dissolved solids | 1,000 |
| Sulfate | 250 | Nitrates | 44 |
| Magnesium | 125 | Flouride | 1.5 |

Water which contains much higher concentrations however, is used in many parts of the United States as well as other parts of the world.

Most of the common constituents in drinking water are objectionable only when the concentrations are high enough to be noticeable to the taste. Because of differences between individuals, objectionable concentrations are difficult to state. Water containing 400-600 ppm chloride is salty to the taste of the average person. People can become accustomed to an objectionable taste if no other source of water is available.

The quality limitations in water for livestock are not as stringent as for human consumption. The upper limits of dissolved solid concentrations in stock waters are reported to range from 5,000 to 15,000 ppm. If the animals are accustomed to highly mineralized water, upper limits of 10,000 to 12,000 ppm dissolved solids can be used as shown in the table below.

| | ppm | | ppm |
|---|---|---|---|
| Poultry | 2,860 | Cattle (Dairy) | 7,150 |
| Pigs | 4,290 | Cattle (Beef) | 10,000 |
| Horses | 6,435 | Adult Sheep | 12,900 |

For the best growth and development of the animals, however, water of quality better than the upper limits indicated is desirable. It is commonly believed that camels have higher tolerance for salts than do most animals.

The concentration and composition of dissolved constituents in a water determine its quality for irrigation use. Quality of water is an important consideration in any appraisal of salinity or alkaline conditions of the soil in an irrigated area.

The characteristics of an irrigation water that appear to be most important in determining its quality are: (1) total concentration of soluble salts; (2) relative proportion of sodium to other cations; (3) concentration of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium.

The total concentration of soluble salts in irrigation waters can be adequately expressed for purposes of evaluation and classification in terms of electrical conductivity (specific conductance). The conductivity is useful because it can be readily and precisely determined. In the classification of irrigation water, conductivity is the measure of the salinity hazard.

In determining the salinity hazard the waters are divided into four groups with respect to conductivity. The limits or dividing points of the classes were determined to be at 250, 750, and 2,250 micromhos/cm (fig. 10).

Figure 10.--Diagram for classification of irrigation waters. (U.S. Salinity Laboratory, 1954).

These class limits were selected in accordance with the relationship between the conductivity of irrigation waters and the saturated extract of the soil. Most waters used for successful irrigation have conductivity values of less than 2,250 micromhos/cm, however, water of higher conductivity can be used in some instances where the soil is well drained and a large percentage of gypsum is present in the soil.

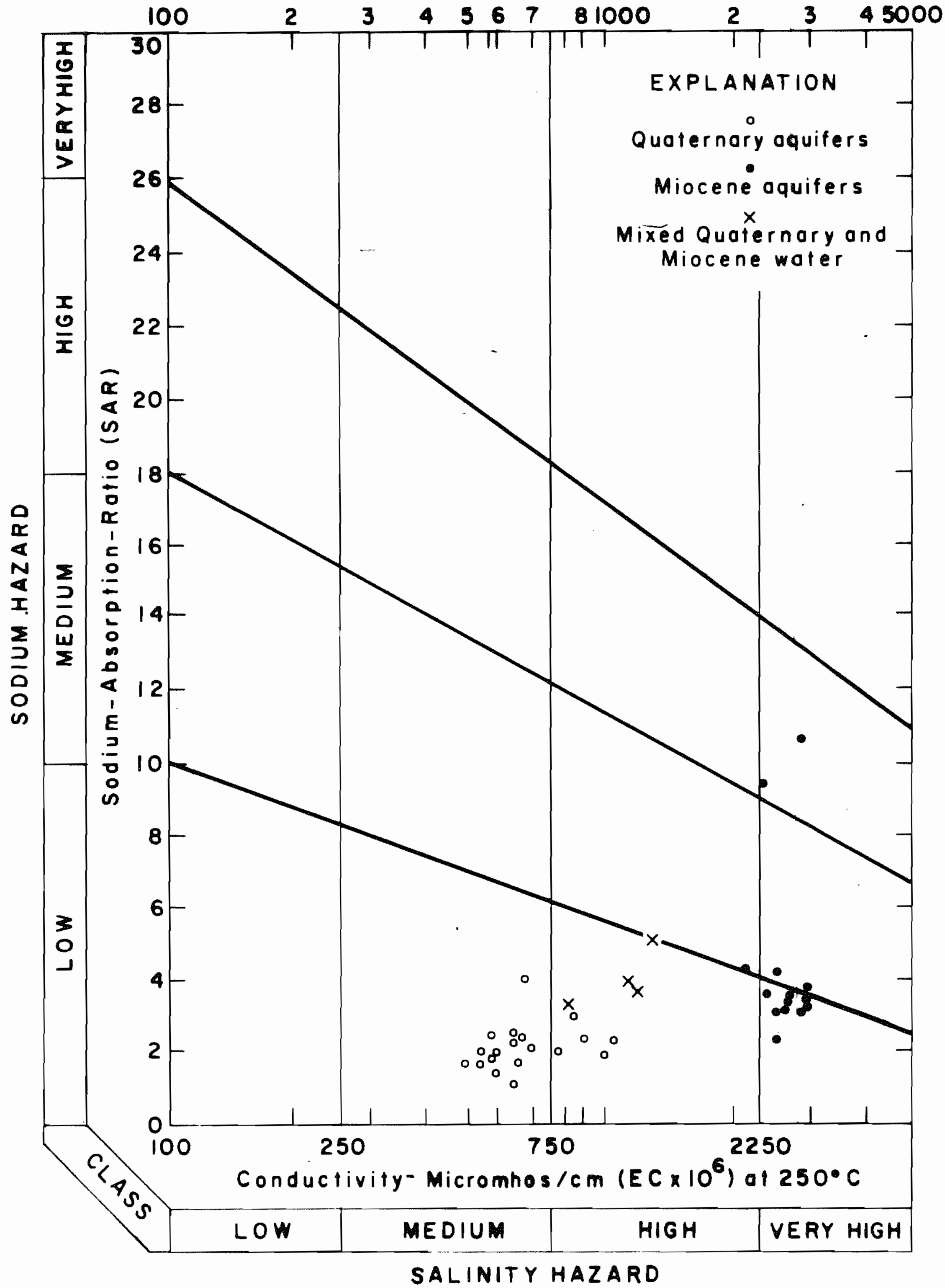


Figure 10.--Diagram for classification of irrigation waters. (U.S. Salinity Laboratory, 1954).

It has been shown that the water-transmission and drainage properties of the soil and the salt tolerance of the crop to be grown are important factors in appraising irrigation waters with respect to total salt concentration.

The soluble inorganic constituents of irrigation waters react with soils as ions. The alkali hazard involved in the use of a water for irrigation is determined by the absolute and relative concentrations of the cations. The sodium-adsorption-ratio (SAR) of a soil solution is related to the adsorption of the sodium by the soil. This ratio is used as an index of the sodium or alkali hazard of the water. This ratio is defined by the empirical equation:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where sodium ($Na^{+}$), calcium ($Ca^{++}$), and magnesium ($Mg^{++}$) represent the concentrations in milliequivalents per liter of the respective ions.

The significance and interpretation of the quality-class ratings on the diagram for the classification of irrigation waters (fig. 10) are summarized below:

Conductivity

Low-salinity water - can be used for irrigation with most crops on most soils, with little likelihood that a salinity problem will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water - can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most instances without special practices for salinity control.

High-salinity water - cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and plants with good salt tolerance should be selected.

Very-high salinity water - is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

Soils may become saline from use of irrigation waters if the drainage is inadequate or water is applied to sparingly. Plant roots take in water but absorb very little salt and evaporation removes the soil water and leaves the salt, consequently an excess amount of salt may accumulate near the base of the root zone and the growth of crops may be curtailed.

This may be controlled by leaching of the soil by the use of excessive irrigation water if the soil drainage is good.

Low sodium water - can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops, such as stone-fruit trees and avocados, may accumulate injurious concentrations of sodium.

Medium-sodium water - will present an appreciable sodium hazard in fine textured soils of high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils that have good permeability.

High-sodium water - may produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and additions or organic matter. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very-high sodium water - is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants may, however, suffer injury as a result of sodium accumulation in plant tissue when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

The control of increased exchangeable sodium, or alkali, resulting from irrigation with waters high in sodium content may require special management practices. As the proportion of exchangeable sodium increases, the physical and chemical conditions of the soil become detrimental to the growth of plants. This can be prevented at times by the addition of gypsum ($CaSO_4 \cdot 2H_2O$) to the water or to the soil. If the soils are highly calcareous or gypsiferous the irrigation water may dissolve sufficient calcium from the soil to decrease and control the sodium hazard.

## Evaluation of water analyses

Water samples were collected for analysis from selected wells in the Qarahbulli area. The results of the chemical analyses of the water are given in table 5. Water from the Quaternary aquifer which is relatively soft and generally contains less than 1,000 ppm of total dissolved solids, is considered suitable for domestic use. The water from Miocene aquifers however, is hard and slightly alkaline and contains generally about 2,000 ppm of total dissolved solids. The water can be used for irrigation, and livestock and also for domestic supply in lieu of better quality water. Chemical data from the water analyses, when plotted on the SAR diagram (fig. 10), fall into three general groups. The water from the Quaternary aquifer is classed a low sodium hazard and a medium-high salinity hazard group. The samples from the Miocene aquifers are classed in the low-medium sodium hazard and high to very high salinity hazard group. The third group appears to be a mixture of Quaternary and Miocene waters which results in a water of low-sodium and high-salinity hazard.

The percent of sodium in the water samples from wells 3242-1339-3 and 3242-1346-2 is exceptionally high and a high sodium hazard is indicated. The reason for this high sodium content is not known, but it may be due to local contamination. The wells are not used for irrigation, and thus there is no danger of inducing alkaline conditions to the soil.

As shown in figure 10 most of the water used for irrigation in the Qarahbulli area has a relatively low sodium content; therefore the danger of toxic effects on plants and permanent damage to the soil structure is small. Higher sodium-hazard waters may be offset by the gypsum content that is common in the soils of Tripolitania.

Table [illegible].--Chemical analyses, in parts per million, of water from typical wells in the Qarahbulli area.

| Well No. | Depth of Aquifer (meters) | Date of Collection | Temperature (°C.) | Iron (Fe) | Silica ($SiO_2$) | pH | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Specific conductance (micromhos at 25°C.) | Dissolved solids at 180°C. | Hardness as $CaCO_3$ | Sodium absorption Ratio (SAR) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3241-1351-2 | 78 | July 1957 | - | - | - | - | 152 | 78 | - | - | 331 | 288 | 355 | - | - | 701 | - |
| 3241-1351-3 | 98 | 12 Sept. 1962 | - | - | - | 7.7 | 59 | 41 | 133 | 6 | 156 | 160 | 206 | 820 | 728 | 315 | 3.26 |
| 3242-1335-1 | 22 | 11 Sept. 1962 | - | - | - | 7.6 | 52 | 23 | 65 | 3 | 224 | 92 | 64 | 645 | 412 | 225 | 1.85 |
| 3242-1336-1 | - | 1940 | - | - | - | - | - | - | - | - | - | - | 53 | - | - | 208 | - |
| 3242-1336-1 | 190 | 27 Jan. 1940 | - | - | 20 | 7.3 | 227 | 119 | 253 | - | 390 | 526 | 488 | 2504 | 1944 | 1200 | 2.39 |
| 3242-1336-2 | 170 | ? | - | Tr | 22 | 7.4 | 244 | 127 | - | - | 190 | 639 | 585 | 2825 | 2260 | 1160 | - |
| 3242-1338-1 | 41 | 13 April 1940 | - | - | - | - | - | - | - | - | - | - | 75 | - | - | 200 | - |
| 3242-1339-2 | - | 15 Sept. 1962 | - | - | - | 7.5 | 52 | 25 | 64 | 4 | 226 | 44 | 85 | 580 | 414 | 233 | 1.83 |
| 3242-1339-3 | 172 | ? | - | 1.4 | 22 | 7.2 | 147 | 131 | 807 | 176 | 81 | 573 | 520 | 2900 | 2461 | 1150 | 11.29 |
| 3242-1341-1 | 51 | 14 Sept. 1962 | - | - | - | 7.7 | 88 | 6 | 70 | 3 | 93 | 87 | - | 600 | 474 | 243 | 1.97 |
| 3242-1342-1 | 29 | 12 Sept. 1962 | - | - | - | 7.8 | 38 | 23 | 57 | 4 | 244 | 33 | 46 | 500 | 338 | 190 | 1.78 |
| 3242-1346-2 | 65 | 12 Sept. 1962 | - | - | - | 7.4 | 80 | 15 | 356 | 9 | 338 | 204 | 390 | 2280 | 1240 | 461 | 9.51 |
| 3242-1356-1 | 55 | 16 Sept. 1962 | - | - | - | 7.7 | 112 | 25 | 171 | 9 | 256 | 118 | 291 | 1250 | 866 | 383 | 3.80 |
| 3242-1359-2 | 76 | 15 Sept. 1962 | - | - | - | 7.7 | 64 | 47 | 224 | 8 | 270 | 165 | 312 | 1350 | 976 | 353 | 5.20 |
| 3243-1336-3 | 264 | ? | - | Tr | 18 | 7.6 | 267 | 98 | - | - | 198 | 620 | 325 | - | 2062 | 1070 | - |
| 3243-1336-3 | 264 | 24 Feb. 1960 | 31 | 0.1 | 17 | 6.9 | 226 | 122 | 243 | 10 | 549 | 669 | 319 | 2515 | 1971 | 1068 | 3.23 |
| 3243-1336-4 | 268 | 18 June 1956 | - | Tr | 42 | 7.3 | 230 | 136 | - | - | 143 | 655 | 350 | - | 2002 | 1045 | - |
| 3243-1336-4 | 268 | 18 June 1956 | - | Tr | 34 | 7.5 | 220 | 133 | - | - | 148 | 665 | 340 | - | 1973 | 1010 | - |
| 3243-1336-4 | 268 | 14 Sept. 1962 | - | - | - | 7.5 | 204 | 127 | 290 | 15 | 545 | 731 | 333 | 3000 | 2008 | 1032 | 3.92 |
| 3243-1339-1 | 29 | 12 Sept. 1962 | - | - | - | 7.9 | 38 | 26 | 84 | 4 | 224 | 74 | 78 | 590 | 438 | 202 | 2.57 |
| 3243-1339-2 | 193 | 11 Feb. 1960 | 30 | - | 10 | 6.8 | 206 | 115 | 262 | 10 | 533 | 633 | 328 | 2450 | 1984 | 989 | 3.63 |
| 3243-1340-1 | 32 | 13 Sept. 1962 | - | - | - | 7.7 | 78 | 33 | 99 | 4 | 203 | 127 | 177 | 1075 | 632 | 380 | 2.36 |
| 3243-1340-2 | 195 | 19 Oct. 1958 | 23 | 0.6 | 13 | 6.8 | 225 | 116 | 245 | 10 | 534 | 658 | 339 | 2632 | 1760 | 1038 | 3.31 |
| 3243-1340-2 | 195 | 13 Aug. 1959 | - | 0.7 | 13 | 6.9 | 223 | 119 | 220 | 10 | 537 | 648 | 321 | 2352 | 1963 | 1047 | 3.01 |
| 3243-1340-2 | 195 | 9 Feb. 1960 | 29 | 1.8 | 6 | 6.9 | 190 | 136 | 262 | 11 | 539 | 670 | 340 | 2714 | 1964 | 1035 | 3.54 |
| 3243-1340-4 | 40 | 14 Sept. 1962 | - | - | - | 7.8 | 46 | 30 | 77 | 3 | 237 | 42 | 113 | 680 | 448 | 239 | 2.17 |
| 3243-1340-5 | 32 | 17 July 1956 | - | Tr | 18 | 7.8 | 39 | 25 | - | - | 38 | 52 | 140 | 702 | 445 | 205 | - |
| 3243-1341-2 | 35 | 11 Sept. 1962 | - | - | - | 7.8 | 32 | 22 | 124 | 6 | 281 | 81 | 85 | 680 | 508 | 171 | 4.10 |
| 3243-1346-1 | 145 | 20 April 1937 | - | - | - | - | - | - | - | - | - | - | 142 | - | 434 | 60 | - |
| 3243-1346-1 | 145 | 29 April 1937 | - | - | - | 8.1 | - | - | - | - | - | - | 136 | 587 | 393 | 30 | - |
| 3243-1346-1 | 266-277 | 23 Oct. 1937 | - | - | 45 | 7.7 | 252 | 112 | 383 | | - | 696 | 394 | 2550 | 2143 | 1058 | 5.05 |
| 3243-1346-1 | 140-272 | 22 Dec. 1937 | 34 | - | 58 | 7.3 | 226 | 128 | 329 | | - | 621 | 460 | 2650 | 2109 | 1069 | 4.33 |
| 3243-1350-1 | 35 | 14 Sept. 1962 | - | - | - | 7.5 | 49 | 26 | 110 | 5 | 284 | 104 | 85 | 860 | 512 | 240 | 3.10 |
| 3243-1356-1 | 20 | 20 April 1938 | - | - | - | - | - | - | - | - | - | - | 296 | - | - | 508 | - |
| 3243-1356-1 | 378 | 23 April 1938 | 22 | - | 2.6 | 7.2 | 105 | 121 | 292 | - | 89 | 658 | 424 | 2176 | 1588 | 710 | 4.50 |
| 3243-1359-1 | 71 | 16 Sept. 1962 | - | - | - | 7.7 | 116 | 23 | 178 | 5 | 257 | 121 | 298 | 1200 | 888 | 394 | 3.95 |
| 3244-1336-2 | 41 | 11 Sept. 1962 | - | - | - | 7.8 | 43 | 22 | 53 | 2 | 198 | 62 | 64 | 645 | 334 | 200 | 1.15 |
| 3244-1337-1 | 180 | 9 Feb. 1960 | 26 | 0.2 | 10 | 7.1 | 174 | 150 | 267 | 23 | 473 | 687 | 574 | 2925 | 2214 | 1053 | 3.58 |
| 3244-1337-2 | 224 | 9 Feb. 1960 | 29.5 | 0.1 | 8 | 7.1 | 181 | 138 | 264 | 10 | 551 | 660 | 330 | 2656 | 1870 | 1015 | 3.60 |
| 3244-1337-3 | 405 | Feb. 1960 | 28.5 | 0.1 | 9 | 6.7 | 226 | 115 | 265 | 17 | 508 | 609 | 401 | 2570 | 1918 | 1081 | 3.51 |
| 3244-1337-4 | 222 | 6 June 1956 | - | Tr | 28 | 7.6 | 250 | 151 | - | - | 313 | 677 | 632 | - | 2416 | 1000 | - |
| 3244-1337-4 | - | 11 Feb. 1960 | 29 | - | 12 | 6.8 | 214 | 117 | 263 | 12 | 538 | 618 | 329 | 2510 | 1906 | 1015 | 3.58 |
| 3244-1340-2 | 17 | 15 Sept. 1962 | - | - | - | 6.5 | 52 | 23 | 70 | 3 | 217 | 70 | 71 | 560 | 428 | 223 | 2.03 |
| 3244-1341-1 | 32 | 14 Sept. 1962 | - | - | - | 7.6 | 56 | 26 | 72 | 3 | 213 | 70 | 113 | 775 | 456 | 250 | 2.17 |
| 3244-1341-9 | 24 | 28 Feb. 1957 | - | Tr | - | - | 95 | 69 | - | - | 301 | 653 | 188 | 1509 | 1105 | 521 | - |
| 3244-1344-2 | 42 | 15 Sept. 1962 | - | - | - | 7.8 | 42 | 28 | 74 | 4 | 255 | 39 | 85 | 640 | 422 | 220 | 2.26 |
| 3245-1337-2 | 139 | 19 April 1957 | - | 23 | 26 | - | 221 | 107 | 253 | 14 | 497 | 653 | 433 | 2866 | 2260 | 1006 | 3.50 |
| 3245-1337-2 | - | 11 Feb. 1960 | 28 | 0.1 | 13 | 7.0 | 234 | 115 | 262 | 15 | 500 | 616 | 431 | 2632 | 2049 | 1058 | 3.51 |
| 3245-1337-2 | - | 14 Sept 1962 | - | - | - | 7.5 | 278 | [illegible] | 279 | 14 | 495 | 640 | 433 | 2100 | 2068 | 1061 | 3.73 |
| 3245-1337-3 | 31 | 11 Sept. 1962 | - | - | - | 7.6 | 114 | 23 | 88 | 3 | 183 | 117 | 212 | 990 | 658 | 330 | 1.96 |
| 3245-1342-2 | 24.26 | 13 April 1940 | - | - | - | - | - | - | - | - | - | - | 61 | - | - | 222 | - |
| 3245-1342-2 | 130 | 28 May 1940 | 30 | - | - | - | - | - | - | - | - | - | 406 | - | - | 1100 | - |
| 3245-1343-2 | 21 | 14 Sept. 1962 | - | - | - | 7.7 | 76 | 33 | 103 | 3 | 227 | 86 | 186 | 910 | 618 | 325 | 2.49 |
| 3245-1349-1 | 31 | 16 Sept 1962 | - | - | - | 7.8 | 44 | 24 | 96 | 4 | 238 | 41 | 106 | 650 | 452 | 210 | 2.59 |
| 3245-1350-2 | 22 | 16 Sept. 1962 | - | - | - | 7.7 | 49 | 23 | 80 | 5 | 262 | 45 | 85 | 660 | 446 | 220 | 2.35 |
| 3247-1330-2 | 34 | 15 Sept. 1962 | - | - | - | 7.9 | 61 | 30 | 54 | 3 | 239 | 53 | 92 | 600 | 430 | 275 | 1.41 |
| 3248-1333-1 | - | 14 Sept. 1962 | - | - | - | 7.8 | 54 | 23 | 62 | 3 | 233 | 34 | 71 | 540 | 408 | 228 | 1.77 |

The soils in the area of study, as in most of the Gefara, are predominantly sandy and thus provide good subsoil drainage. Under these conditions control of salinity can be readily attained by leaching of the soil with additional irrigation water. Of the many crops grown in this area citrus fruit, almonds, and potatoes have a reported low salinity tolerance, whereas figs, grapes, olives, alfalfa, barley, peanuts, and tomatoes have a moderate to high salinity tolerance. Date palms and tobacco have a high salinity tolerance. Most of the crops grown in this area, as shown above, appear to have a moderate to high tolerance to salinity and do not present problems that cannot be ameliorated by judicious irrigation management and leaching procedures.

There appear to be few if any quality of water problems in the area at this time (1962). Most of the areas of agricultural development are located at considerable distance from the sea, thus, the possibility of salt-water encroachment does not currently (1962) appear to be imminent.

## Conclusions

There are two principal water-bearing formations in the Qarahbulli area containing water of quality generally suitable for irrigation and domestic supply. Water from the shallow Quaternary aquifer generally contains less than 1,000 ppm of total dissolved solids and is well suited for both domestic supply and irrigation. Water from the Miocene artesian aquifers generally contains from 1,500 to 2,400 ppm of total dissolved solids and is suitable for irrigation. This water can be used for domestic supply in lieu of water of better quality.

Comparative measurements show that the water levels in the Quaternary aquifer in the developed area near Qasr al Qarahbulli declined about 0.2 m in 1961-62. This rate of decline is not alarming, but over a period of years could accumulate to several meters and necessitate the deepening of wells and the avampozzos. The hydrostatic pressure of the Miocene artesian aquifers currently (1962) appears to be declining at 0.4 to 0.6 m per year near El Guea. East of Qasr al Jifarah, wells penetrating the upper Miocene strata declined about 0.5 m in 1961-62. The effects of the decline of the water levels in the Miocene aquifers will be quite apparent as soon most of the artesian wells will require pumps to lift the water required for irrigation. Therefore, judicious use of the water should be exercised as the decline may continue at an increased rate.

The yields of many of the wells could be increased by using modern water well construction methods. Wells should completely penetrate the water-bearing formation and be cased and screened (or slotted pipe) to the bottom of the well.

In recent years efforts have been made to cultivate the flat-lying areas interspersed among the sand dune areas along the coast and in the western part of the area. This practice should be encouraged for it has potential for small scale farming.

Several wells penetrating Cretaceous (?) rocks tapped aquifers which contained water of unknown quality. If these aquifers contain water of suitable quality for irrigation, they represent a potential source for future development.

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Notes to accompany Table 4.

1/ The spellings of the cabilas and owners' names follow those of the field notes.

2/ Dr, drilled. All drilled wells in this report are put down in dug wells that extend to a short distance above the water table.

3/ Chemical analyses are given in table 5. Conductivity = specific conductance in micromhos at 25°C.

4/ Abbreviations of crops grown in area; Al-Alfalfa, Ap-Apricots, Ba-Barley, Be-Beans, Co-Corn, Gr-Grapes, Me-Melons, Ol-Olives, On-Onions, Or-Oranges, Pe-Peanuts, Po-Potatoes, Pp-Peppers, To-Tomatoes, Ve-Vegetables

5/ Aquifer; (M) Miocene strata, (Q) Quaternary deposits.

6/ Aban-abandoned, Dom-domestic, Irr-irrigation, Obs-observation well, Ps-public supply, S-stock, Un-unused.

Table 4.--Records of typical wells in the Qarahbulli area.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3241-1333-1 | Al Qarahbulli, Bir Sabera<br>Cabila Ziaina | - | 31.8 | Dug | - | Q | 28.50 | 23 Aug. 53 | - | - | - | Dom,<br>S | 1,000 | - |
| 3241-1338-1 | Al Qarahbulli, Bir Bu'Hadna<br>Government well | - | 23.1 | Dug | - | Q | 23.00 | 19 Aug. 53 | - | - | - | Dom,<br>S | 1,000 | - |
| 3241-1338-2 | Al Qarahbulli, Bir Amarien | - | - | - | - | - | - | - | - | - | - | - | 1,000 | - |
| 3241-1350-1 | Qasr al Jifarah<br>Cabila Rahebat, Ulad Ahmed | - | 47.60 | Dug | - | Q | 43.90<br>43.79<br>44.00 | 2 May 53<br>18 Apr. 61<br>21 Apr 62 | - | - | - | Dom,<br>S | 1,000 | - |
| 3241-1351-1 | Qasr al Jifarah<br>Federal Government | - | - | Dr. | 1935 | M | - | - | - | - | - | Un. | - | - |
| 3241-1351-2 | Qasr al Jifarah<br>Naz. of Agriculture | - | 78.00 | Dr. | 1957 | M | 41.72<br>41.95 | 19 July 58<br>30 Sept. 62 | - | - | - | Obs.<br>Un. | - | Chemical analysis |
| 3241-1351-3 | Qasr al Jifarah<br>Municipality | - | 88.00 | Dr. | 1956 | M | 71.30<br>71.30 | 6 Feb. 61<br>19 May 62 | 15 | - | - | Ps | 10,000 | Chemical analysis |
| 3241-1359-1 | Ganima<br>Hag Mohamed Etmuni | - | 58.00 | Dr. | 1935 | Q | 38.40<br>39.05 | 8 Feb. 61<br>19 May 62 | - | - | - | Dom,<br>S | 2,000 | - |
| 3242-1333-1 | Bir Semelghi<br>Muaigia | - | 4.58 | Dug | - | Q | 3.55 | 26 Aug. 53 | - | - | - | Dom,<br>S | 1,000 | - |
| 3242-1335-1 | El Guea<br>Bir El Saada | - | 21.70 | Dug | - | Q | 21.30<br>19.05 | 25 Oct. 60<br>30 Jan. 62 | - | - | - | Dom,<br>S | 1,000 | Chemical analysis |
| 3242-1336-1 | Al Qarahbulli (INPS)<br>Libyan Government | 85.00 | 231 | Dr. | 1940 | M | - | - | - | - | - | Aban. | - | Log, OPDL 70<br>Chemical analysis |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3242-1336-2 | Al Qarahbulli-(Bianchini) Government | - | 214 | Dr. | - | M | 35.30 | 26 July 56 | 40 | - | - | - | 100,000 | Chemical analysis |
| 3242-1336-3 | El Guea Bir el Tushani | - | 23.80 | Dug | - | Q | 23.40<br>23.31<br>23.27 | 25 Oct. 60<br>26 Mar. 61<br>27 Mar. 62 | - | - | - | Dom. S | 2,000 | - |
| 3242-1337-1 | El Guea Bir Salem Bu Rahuma | - | 21 | Dug | - | Q | 20.52 | 25 Aug. 53 | - | - | - | Aban. | - | - |
| 3242-1338-1 | El Guea Libyan Government | - | 338.65 | Dr. | 1940 | M | 30.50 | - | - | - | - | Aban. | - | Chemical analysis Log, OPDL 69 |
| 3242-1339-1 | Al Qarahbulli Mohamed ben Ahmed | - | 37.80 | Dr. | 1960 | Q | 22.20<br>22.45 | 17 Jan. 61<br>24 Mar. 62 | 40 | 3/4 | Al, Pe | Irr. | 18,000 | - |
| 3242-1339-2 | Al Qarahbulli Maammer ben Aghel | - | 37.50 | Dr. | 1960 | Q | 22.05<br>22.11 | 17 Jun 61<br>Mar. 62 | 40 | 1/6 | Al, Be | Irr. | 8,000 | - |
| 3242-1339-3 | Al Qarahbulli Government sheep ranch | - | 17.8 | Dr. | 1956 | M | 40.0 | 1956 | 25 | - | - | Dom. S. | 10,000 | Chemical analysis Log, USOM No. 29 |
| 3242-1339-4 | Al Qarahbulli Bir Esc Scit | - | 25.30 | Dug | - | Q | 24.58 | 25 Aug.53 | - | - | - | Aban. | - | - |
| 3242-1340-1 | Al Qarahbulli Hag Salem | - | 34.15 | Dr. | 1959 | Q | 21.92<br>22.12 | 17 Jan. 61<br>24 Mar. 62 | 60 | 8 | Gr,Ba | Irr. Dom. S | 80,000 | - |
| 3242-1341-1 | Al Qarahbulli, Bir Sidi Bu-Sbeto. Amedia Gerardia | - | 51 | Dr. | - | Q | 47.2 | 21 Aug. 62 | - | 1 | Ol | Dom. S | 10,000 | Chemical analysis |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3242-1342-1 | Al Qarahbulli<br>Dott. Bardi and Dott. Vierani | - | 29.80 | Dug | - | Q | 27.52<br>27.60 | 26 Jan. 61<br>27 Mar. 62 | - | 1 | Ol, Ve | Irr.<br>Dom,S | 6,000 | Chemical analysis |
| 3242-1346-1 | Al Qarahbulli<br>Com. Popgi (ex FATMA) | - | 60+ | Dr. | - | M | 44.14<br>44.52 | 2 Mar. 53<br>27 Aug. 62 | - | - | - | Dom,<br>S | 13,000 | - |
| 3242-1346-2 | Bir Madrast Shredat<br>do | - | 65.50 | Dr. | 1956 | M | 40.90<br>40.00 | 6 Feb. 61<br>27 Mar. 62 | - | - | - | Dom,<br>S | 3,000 | Chemical analysis |
| 3242-1352-1 | Qasr al Jifarah- N. of Km 78<br>Ali ben Salem | - | 70 | Dr. | 1935 | M | 43<br>43.50 | 30 Jun. 61<br>19 May 62 | 15 | 2 | Al, Be | Irr.<br>Dom,S | 21,000 | - |
| 3242-1356-1 | Qasr al Jifarah-near Km 84<br>Hag Ali Arafu & Co. | - | 55.60 | Dr. | 1931 | Q | 41.00<br>41.38 | 7 Feb. 61<br>22 Apr. 62 | 40 | 7 | Or | Irr.<br>Dom,S | 34,000 | Chemical analysis |
| 3242-1356-2 | Qasr al Jifarah-near Allus<br>Giaccomo Calo | - | 59.70 | Dr. | 1931 | Q | 41.75<br>42.15 | 7 Feb. 61<br>22 Apr. 62 | 35 | 7 | Or | Irr.<br>Dom,S | 75,000 | - |
| 3242-1357-1 | Qasr al Jifarah-near Allus<br>Hag Buzed & Co. | - | 62.20 | Dr. | 1957 | Q | 46.70<br>47.25 | 8 Feb. 61<br>22 Apr. 62 | 35 | 2 | Ba, Be | Irr.<br>Dom,S | 20,000 | - |
| 3242-1358-1 | Qasr al Jifarah-at Ghnima<br>Giaccomo Calo | - | - | Dr. | 1936 | Q | 40.25<br>40.44 | 7 Feb. 61<br>27 Mar. 62 | - | - | - | Un. | - | - |
| 3242-1359-1 | Qasr al Jifarah-Km 89, Ghnima<br>Mehemed Bareson Silvio | - | 92.00 | Dr. | 1958 | M | 38.00<br>38.10 | 9 Feb. 61<br>19 May 62 | - | 1/4 | Al | Irr.<br>Dom,S | 4,000 | - |
| 3242-1359-2 | Qasr al Jifarah-Ghnima, Km 89<br>Abdussalamel Gerbi | - | 76.60 | Dr. | 1935 | M | 39.25<br>39.37 | 8 Feb. 61<br>19 May 62 | - | 1/2 | Or, Al | Irr.<br>Dom,S | 6,000 | Chemical analysis |
| 3243-1336-1 | El Guea-S. Km 50<br>Sheikh Abdallah | - | 28.60 | Dr. | 1959 | Q | 27.92 | 18 Oct. 60 | - | - | - | Obs. | - | Recorder installed 1961 |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3243-1336-2 | El Guea-near Km 51<br>Public well | - | 28.80 | Dug | 1953 | Q | 27.20<br>27.91 | 19 Aug. 53<br>26 Jan. 61 | - | - | - | Dom.<br>S | 1,000 | - |
| 3243-1336-3 | El Guea-near Km 51<br>Government well | 60.237 | 264 | Dr. | 1956 | M | 3.0 | 16 July 56 | 110 | 50 | Be, Al | Irr. | 250,000 | Chemical analysis<br>Log, USOM 29 |
| 3243-1336-9 | El Guea-near Km 51<br>Dept. of Agriculture | 65.352 | 268 | Dr. | 1956 | M | 8.23<br>10.57 | 16 July 56<br>25 Aug. 59 | 110 | 50 | Ba | Irr. | 250,000 | Obs.well 1959-61, chemical analysis, log |
| 3243-1338-1 | El Guea<br>Sciaref ben Mohamed | - | 22.67 | Dug | - | Q | 22.61 | 25 Aug. 53 | - | - | - | Aban. | - | - |
| 3243-1339-1 | El Guea-near Km 56<br>Giuma ben Hag | - | 29.00 | Dr. | 1960 | Q | 24.40<br>24.62 | 23 Jan. 61<br>24 Mar. 62 | 35 | 1 | Be, Ol | Irr.<br>Dom,S | 15,000 | Chemical analysis |
| 3243-1339-2 | El Guea-near Km 56<br>Libyan Government | 52.544 | 193 | Dr. | 1939 | M | Flow<br>+6.5 | 1939 | - | - | - | - | 150,000 | Chemical analysis<br>Log, OFDL 59 |
| 3243-1339-3 | El Guea-S. of Km 56<br>Khalifa ben Hag Salem | - | 25.80 | Dr. | 1960 | Q | 17.75<br>17.95 | 17 Jan. 61<br>24 Mar. 62 | 25 | 4 | Be, Pe | Irr.<br>Dom,S | 47,000 | - |
| 3243-1339-4 | El Guea-S. of Km 56<br>Mohamed ben Ahmed | - | 18.80 | Dug | 1911 | Q | 18.29<br>18.32 | 17 Jan. 61<br>24 Mar. 62 | - | - | - | Dom,S | 3,000 | - |
| 3243-1340-1 | Al Qarahbulli, Cabila Ruagia<br>Hag Ammar | - | 32.7 | Dr. | 1959 | Q | 26.15 | 28 May 62 | 60 | 3 | Pe, Al | Irr.<br>Dom,S | 34,000 | Chemical analysis |
| 3243-1340-2 | Al Qarahbulli<br>Dept. of Agriculture | 51.904 | 195 | Dr. | 1958 | M | Flow<br>+5.0 | 1958 | - | 4 | Al | - | 55,000 | Chemical analysis |
| 3243-1340-3 | Al Qarahbulli<br>Dott. Bardi Viuraui | - | 24 | Dug | - | Q | 18.00<br>18.50 | 2 Feb. 57<br>21 April 62 | 34 | - | - | Dom,S | 3,000 | - |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3243-1340-4 | Al Qarahbulli, Bir Sidi On<br>Amedia Gerardi | - | 39.75 | Dr. | 1930 | Q | 35.36 | 21 Aug. 62 | - | | Ol,Or | Dom,S<br>Irr. | 50,000 | Chemical analysis |
| 3243-1340-5 | Al Qarahbulli, Km 57<br>Government Farm | - | 32 | Dr. | - | Q | 21 | 28 Aug. 56 | 22 | - | - | Dom,<br>S | 3,000 | Chemical analysis |
| 3243-1341-1 | Al Qarahbulli<br>Dott. Bardi Viarani | 49.408 | 187.2 | Dr. | 1937 | M | +8.0<br>0.70 | 20 Jun. 37<br>18 Aug. 62 | 60 | 20 | Pe,Ol,Or | Irr.<br>Dom,S | 200,000 | Log, OPDL 19 |
| 3243-1341-2 | Al Qarahbulli<br>Dott. Bardi Viarani | - | 35.70 | Dr. | 1920 | Q | 27.40<br>27 | 16 Nov. 60<br>18 Aug. 62 | 12 | 3 | Or | Irr.<br>Dom,S | 30,000 | Chemical analysis |
| 3243-1345-1 | Al Qarahbulli<br>Car. Latansi | - | - | Dr. | 1935 | Q | 46.35 | 18 Jan. 61 | - | - | - | Dom,S | 3,000 | - |
| 3243-1346-1 | Concessione FATMA<br>Qarahbulli | 55.12 | 308 | Dr. | 1937 | M | 14.5<br>17.43<br>17.40<br>17.48 | 23 Sept. 37<br>11 May 60<br>29 April 61<br>25 May 62 | 78 | - | - | Irr. | 100,000 | Log, OPDL 11<br>Chemical analysis |
| 3243-1350-1 | Qasr al Jifarah-Cabila<br>Rhebat<br>Hasen ben Hag Mohamed | - | - | Dug | 1958 | Q | 35.00 | 27 Aug. 62 | - | - | - | Dom,S | 1,000 | Log, OPDL 18<br>Chemical analysis |
| 3243-1356-1 | Qasr al Jifarah<br>Concessione Calo | 60.000 | 378.50 | Dr. | - | M | 22.00 | 31 Mar. 38 | - | - | - | Aban. | - | Chemical analysis |
| 3243-1359-1 | Ganima<br>Ali Mohamed Hsciur | - | 71 | Dr. | 1959 | Q | 34.65<br>40.15 | 9 Feb. 61<br>19 May 62 | - | 1/10 | - | Irr.<br>Dom,S | 1,000 | Chemical analysis |
| 3244-1336-1 | El Guea<br>Guiseppe Lunetto | - | 38.50 | Dr. | 1955 | Q | 21.75<br>22.07<br>21.60 | 25 Oct. 60<br>26 Mar. 61<br>29 Jan. 62 | 60 | 4 | Or,Ol | Irr.<br>Dom,S | 50,000 | - |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3244-1336-2 | El Guea-Km 49<br>Piaggio Bineda | - | 41.00 | Dr. | 1951 | Q | 24.62<br>25.35<br>25.13 | 16 Oct. 60<br>26 Mar. 61<br>29 Jan. 62 | 37 | 6 | Or,Ol,Pe | Irr.<br>Dom,S | 70,000 | Chemical analysis |
| 3244-1336-3 | El Guea, Km 50.5<br>Sheikh Abdallah | - | 52.80 | Dr. | 1959 | Q | 29.80<br>29.98 | 16 Oct. 60<br>27 Mar. 61 | - | - | - | Dom,S | 2,000 | - |
| 3244-1337-1 | El Guea<br>Libyan Government well | 43.775 | 180.50 | Dr. | 1953 | M | Flow<br>+9.5 | 16 Jan. 56 | 50 | 10 | Or | Irr. | 100,000 | Chemical analysis<br>Log, USOM 3 |
| 3244-1337-2 | El Guea<br>Libyan Government well | 44.457 | 224 | Dr. | 1958 | M | Flow | - | 180 | 8 | Al | Irr. | 100,000 | Chemical analysis<br>Log |
| 3244-1337-3 | El Guea<br>Libyan Government well | 45.709 | 404 | Dr. | 1953 | M | Flow<br>+12 | 18 Jan. 56 | 140 | - | - | Irr. | 100,000 | Chemical analysis<br>Log, USOM 2 |
| 3244-1337-4 | El Guea<br>Libyan Government well | 47.554 | 222.16 | Dr. | 1957 | M | Flow<br>+9.9 | 2 Mar. 56 | 180 | 9 | Al | Irr. | 130,000 | Chemical analysis<br>Log, USOM 21 |
| 3244-1340-1 | Al Qarahbulli,Cabila Attaia<br>Mohamed ben Hag Fituri | - | 32.05 | Dr. | 1961 | Q | 16.12 | 19 Aug. 62 | - | 5 | Pe | - | 30,000 | - |
| 3244-1340-2 | Al Qarahbulli,Cabila Attaia<br>Hag Ali ben Milad | - | 16.95 | Dug | - | Q | 16.50 | 19 Aug. 62 | - | 1/2 | Pe,Pp | Irr. | 3,000 | Chemical analysis |
| 3244-1340-3 | Al Qarahbulli<br>Amedea Gerardi | - | 38 | Dr. | 1945 | Q | 26.0 | 19 Aug. 62 | 30 | 3 | Or. | Irr.<br>Dom,S | 40,000 | - |
| 3244-1341-1 | Al Qarahbulli<br>Francesco Mistrella | - | 32.0 | Dr. | 1932 | Q | 17.96<br>19.00 | 25 Aug. 53<br>23 May 62 | 60 | 9 | Pe,To | Irr.<br>Dom,S | 129,000 | Chemical analysis |
| 3244-1341-2 | Al Qarahbulli<br>Francesco Mistrella | - | 31.5 | Dr. | 1960 | Q | 17.00 | 22 May 62 | 50 | 6 | Pe | Irr.<br>Dom,S | 85,000 | - |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3244-1341-3 | Al Qarahbulli,Cabila Attaia<br>Metigh ben Mohamed Hag Hsen | - | 27 | Dr. | 1960 | Q | 14.72 | 16 June 62 | 50 | 4 | Pe,Pp,Al | Irr.<br>Dom,S | 40,000 | - |
| 3244-1341-4 | Al Qarahbulli,Cabila Attaia<br>Kalifa ben Massud | - | 26.20 | Dr. | 1958 | Q | 18.30 | 16 June 62 | - | 2 1/2 | On,Co,Pe,Al | Irr. | 25,000 | - |
| 3244-1341-5 | Al Qarahbulli,Cabila Attaia<br>Hag Ali Agareb | - | 34.62 | Dr. | 1957 | Q | 19.20 | 18 Aug. 62 | 60 | 5 | Pe,Al,Pp | Irr. | 50,000 | - |
| 3244-1341-6 | Al Qarahbulli-Km 59<br>Dott. Bardi Vierani | - | 34.40 | Dr. | 1946 | Q | 19.45<br>19.65 | 26 Jan. 61<br>19 May 62 | 60 | 20 | Ba,Ol,Pe | Irr. | 160,000 | - |
| 3244-1341-7 | Al Qarahbulli<br>Hag Ali | - | 31.20 | Dr. | 1958 | Q | 18.00<br>18.12 | 23 Jan. 61<br>19 May 62 | 50 | 3 | Be,Po,On | Irr. | 30,000 | - |
| 3244-1341-8 | Al Qarahbulli-SE of Km 58<br>Hag Mehemed Agareb | - | 29.90 | Dr. | 1958 | Q | 18.85<br>18.99 | 23 Jan.61<br>19 May 62 | 50 | 5 | Pe,Ol | Irr.<br>Dom,S | 50,000 | - |
| 3244-1341-9 | Al Qarahbulli<br>Bardi-Viarani | - | 26 | Dr. | - | Q | 16.50<br>16.10 | 20 April 62<br>28 Feb. 57 | 60 | 16 | Pe | Irr.<br>Dom,S | 220,000 | Chemical analysis |
| 3244-1342-1 | Al Qarahbulli,Cabila Crawa<br>Mohamed ben Shahma | - | 24.85 | Dr. | 1958 | Q | 20.20<br>22.30 | 20 Oct. 60<br>22 Aug. 62 | 24 | 1 | Pp, Pe,Al | Irr.<br>Dom,S | 14,000 | - |
| 3244-1342-2 | Al Qarahbulli,Cabila Crawa<br>Ahmed Mohamed Ballut | - | 27.10 | Dr. | 1952 | Q | 21.10 | 22 Aug. 62 | - | - | - | Irr. | 20,000 | Chemical analysis |
| 3244-1342-3 | Al Qarahbulli,Cabila Crawa<br>Giuma ben Ali Mjewghi | - | 33.45 | Dr. | 1961 | Q | 23.45 | 19 Aug. 62 | 50 | 7 | Pe | Irr.<br>Dom,S | 50,000 | - |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3/hr$) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3244-1342-4 | Al Qarahbulli,Cabila Crawa<br>Mohamed Ballut | - | 38 | Dr. | 1960 | Q | 20<br>19.85<br>19.92 | 28 Aug. 60<br>6 May 61<br>30 Jan. 62 | - | - | - | - | 20,000 | - |
| 3244-1342-5 | Al Qarahbulli,Cabila Crawa<br>Salah Nasc Hnish | - | 28.20 | Dr. | 1960 | Q | 18.00<br>17.10 | May 60<br>26 Jan. 62 | - | 3 | - | - | 30,000 | - |
| 3244-1343-1 | Al Qarahbulli,Cabila Crawa<br>Miskin ben Mohamed Mherigh | - | 28.10 | Dug | - | Q | Dry | - | - | - | - | Dry | - | - |
| 3244-1343-2 | Al Qarahbulli,Cabila Crawa<br>Khalifa ben Hag Hsen | - | 24.05 | Dr. | 1958 | Q | 21.41 | 22 Aug.62 | 30 | 3 | Pe,Pp | Irr. | 40,000 | - |
| 3244-1343-3 | Al Qarahbulli, S. of Km 62<br>Mohamed ben Massaud Shaktur | - | 31.95 | Dr. | 1928 | Q | 27.41<br>27.00<br>27.49<br>28.17 | 22 Nov. 60<br>27 Mar. 61<br>29 Jan. 62<br>21 Aug.62 | 10 | 4 | Or,Pe,01 | Irr.<br>Dom,S | 25,000 | - |
| 3244-1343-4 | Al Qarahbulli, near Km 63<br>Sayed Adhem Muntasser | - | 32.3 | Dr. | - | Q | 27.25<br>28.47<br>28.55 | 2 Mar. 53<br>18 April 61<br>22 April 62 | - | - | - | Dom,S | 2,000 | - |
| 3244-1343-5 | Al Qarahbulli<br>Giuseppe Ferrera | - | 33.80 | Dr. | 1927 | Q | 30.57<br>31.22 | 22 Nov. 60<br>21 Aug.62 | 40 | 10 | 01,Or | Irr.<br>Dom,S | 100,000 | - |
| 3244-1344-1 | Al Qarahbulli,Cabila Crawa<br>Mohamed ben Khalifa Lamary | - | 27.35 | Dr. | 1961 | Q | 20.75 | 27 Aug. 62 | 20 | 10 | Pe,Or,Pp,Al | Irr.<br>Dom,S | 50,000 | - |
| 3244-1344-2 | Al Qarahbulli, Km 65<br>Latansi well No. 64 | - | 42.60 | Dr. | 1930 | Q | 32.25 | 21 Aug. 62 | 40 | 300 | 01 | Irr.<br>Dom,S | 100,000 | - |
| 3244-1349-1 | Qasr al Jifara,Cabila Amarna<br>Ali ben Ahmed | - | 29.75 | Dug | - | Q | 24.10 | 27 Aug. 62 | - | - | - | Dom,S | 1,000 | - |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3245-1334-1 | West of El Guea<br>Bir Nascra | - | 12.8 | Dug | - | Q | 12.69 | 19 Aug. 53 | - | - | - | Dry | - | - |
| 3245-1337-1 | El Guea<br>Libyan Government | - | 27.2 | Dr. | - | Q | 20.21 | 20 July 53 | - | - | - | Aban. | - | - |
| 3245-1337-2 | El Guea<br>Hag Mustafa Sarrage | 35.514 | 189 | Dr. | 1939 | M | +14.<br>Flowing | 1939 | 70 | 4 | 01,Al | Irr. | 40,000 | Chemical analysis<br>Log, OPDL 89 |
| 3245-1337-3 | El Guea<br>Hag Mustafa Sarrage | - | 30.12 | Dr. | 1955 | Q | 18.61<br>18.78<br>18.87<br>19.29 | 22 Aug. 59<br>20 Oct. 60<br>6 April 61<br>29 Jan. 62 | - | - | - | Dom,S | 1,000 | Chemical analysis |
| 3245-1342-1 | Al Qarahbulli,Cabila Ataia<br>Sheikh Salhin | - | 34.5 | Dr. | 1959 | Q | 20.92 | 28 May 62 | 28 | 6 | Pe,Pp | Irr.<br>Dom,S | 35,000 | - |
| 3245-1342-2 | Al Qarahbulli<br>Government of Libya | - | 264 | Dr. | 1940 | M | 2.5 | 1940 | - | - | - | Aban. | - | Chemical analysis<br>Log, OPDL 82 |
| 3245-1342-3 | Al Qarahbulli,Cabila Crawa<br>Salem Hcascio | - | 21 | Dug | - | Q | 4.0<br>3.85<br>3.95 | April 60<br>28 April 61<br>29 Jan. 62 | - | - | - | Irr.<br>Dom,S | 3,000 | - |
| 3245-1342-4 | Al Qarahbulli,Cabila Crawa<br>Abdussalam Autut | - | 17 | Dr. | 1960 | Q | 6.0<br>6.05<br>6.04 | April 60<br>28 April 61<br>30 Jan. 62 | - | - | - | Irr.<br>Dom,S | 5,000 | - |
| 3245-1343-1 | Al Qarahbulli,Cabila Crawa<br>Hadi Zarrugh | - | 24.65 | Dr. | 1952 | Q | 16.79 | 22 Aug. 62 | 8-10 | 2 1/2 | Pe,Or,01<br>Be,Ba | Irr.<br>Dom,S | 15,000 | Original yield 40 $m^3$/hr, now dry after 1/2 hr |
| 3245-1343-2 | Al Qarahbulli,Cabila Crawa<br>Hag Bashir Lamary | - | 21.65 | Dr. | 1956 | Q | 16.61 | 22 Aug. 62 | - | 10 | - | Irr.<br>Dom,S | 50,000 | Chemical analysis |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3245-1343-3 | Al Qarahbulli,Cabila Crawa<br>Mohamed ben Nasser | - | 32 | Dr. | 1960 | Q | 16.65<br>16.70 | 19 April 61<br>26 Jan. 62 | - | - | - | Irr. | 15,000 | - |
| 3245-1343-4 | Al Qarahbulli,Cabila Crawa<br>Hag Salem Zarrugh | - | 26.60 | Dr. | 1960 | Q | 20.00<br>15.73<br>15.85 | 28 Feb. 60<br>19 April 61<br>27 Jan. 62 | - | 3 | - | Irr. | 20,000 | - |
| 3245-1343-5 | Al Qarahbulli,Cabila Crawa<br>Muftah Mohamed Barcat | - | 21.5 | Dr. | 1960 | Q | 13.00<br>13.00<br>13.00 | April 60<br>19 April 61<br>26 Jan. 62 | - | - | - | Irr. | 10,000 | - |
| 67 3245-1343-6 | Al Qarahbulli,Cabila Crawa<br>Brahim Gerbi | - | 33.30 | Dr. | 1960 | Q | 16.0<br>15.40<br>15.50 | May 60<br>19 April 61<br>27 June 62 | - | 1 1/2 | - | Irr. | 12,000 | - |
| 3245-1345-1 | Mohamed Scialabi<br>do | - | 19 | Dr. | 1960 | Q | 8.5<br>8.85<br>8.97 | April 60<br>29 April 61<br>30 Jan. 62 | - | - | - | Irr. | 10,000 | - |
| 3245-1345-2 | Al Qarahbulli,Cabila Crawa<br>Abdussalam ben Nasser | - | 21.5 | Dr. | 1960 | Q | 8.02<br>8.10 | May 61<br>30 June 62 | - | - | - | Irr. | 10,000 | - |
| 3245-1349-1 | Qasr al Jifarah,Cabila Adul<br>Mehemed Mohamed Lasheb | - | 31.25 | Dr. | 1960 | Q | 20.24 | 28 Aug. 62 | 75 | 10 | Pe,To | Irr. | 100,000 | Chemical analysis |
| 3245-1350-1 | Qasr al Jifarah,Cabila Adul<br>Mohamed ben Hag Hadi | - | 22.15 | Dr. | 1961 | Q | 8.41 | 28 Aug. 62 | - | 10 | Pe,On,To,Pp | Irr.<br>Dom,S | 100,000 | - |
| 3245-1350-2 | Qasr al Jifarah,Cabila Adul<br>Hassen ben Hammali | - | 21.65 | Dr. | 1961 | Q | 15.74 | 28 Aug. 62 | 40 | 8 | To,Or,Pe,Pp | Irr.<br>Dom,S | 86,000 | - |
| 3245-1350-3 | Mohamed ben Saad<br>Mohamed ben Saad Hsen | - | 26.45 | Dr. | 1961 | Q | 19.09 | 28 Aug. 62 | 60 | 8 | Pp,Or,Pe,To | Irr.<br>Dom,S | 89,000 | - |

Table 4.--Records of typical wells in the Qarahbulli area Cont'd.

| WELL NUMBER | LOCATION AND OWNER 1/ | ELEVATION ABOVE SEA LEVEL (meters) | DEPTH (meters) | TYPE OF WELL 2/ | YEAR CONSTRUCTED | AQUIFER 5/ | DEPTH TO WATER BELOW LAND SURFACE (meters) | DATE OF MEASUREMENT | REPORTED YIELD ($m^3$/hr) | HECTARES IRRIGATED | CROPS IRRIGATED 4/ | USE 6/ | ANNUAL DISCHARGE ($m^3$) | REMARKS 3/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3245-1350-4 | Qasr al Jifarah, Cabila Shurfa<br>Hassen ben Ali | - | 21.85 | Dug | 1962 | Q | 21.50 | 27 Aug. 62 | - | - | - | Dom,S | 1,000 | - |
| 3246-1330-1 | Cabila Enshia, S. of Km 32<br>Taher Luti | - | 32.40 | Dr. | 1958 | Q | 8.12 | 11 Sept. 62 | 30 | 4 | Pe,Al | Irr.<br>Dom,S | 50,000 | - |
| 3246-1330-2 | Cabila Enshia, S. of Km 32<br>Hag Abdussalam | - | 27.70 | Dr. | 1958 | Q | 7.60 | 11 Sept. 62 | 35 | 4 | On,Al,Pe,Pp | Irr.<br>Dom,S | 40,000 | - |
| 3246-1332-1 | Bir Zregh<br>do | - | 25.70 | Dug | - | Q | 22.57 | 18 Aug. 53 | - | - | - | Dry | - | - |
| 3246-1350-1 | Qasr al Jifarah, Cabila Adul<br>Hag Ahmeda Fhed | - | 29.45 | Dr. | 1961 | Q | 16.54 | 28 Aug. 62 | 40 | 10 | On,Pe,To,Po | Irr.<br>Dom,S | 108,000 | - |
| 3246-1351-1 | Qasr al Jifarah, Cabila Adul<br>Hassen ben Hag Muftah | - | 26.45 | Dr. | 1961 | Q | 16.95 | 28 Aug. 62 | - | 8 | To,On,Pe,Pp | Irr.<br>Dom,S | 90,000 | - |
| 3247-1330-1 | Cabila Enshia, S. of Km 32<br>Abdussalam Debr | - | 31.30 | Dr. | 1961 | Q | 7.86 | 11 Sept. 62 | 25 | 4 | Pe,To,Al,Me | Irr.<br>Dom,S | 45,000 | - |
| 3247-1330-2 | Cabila Enshia, S. of Km 32<br>El Fazael Debr | - | 34.00 | Dr. | 1960 | Q | 6.44 | 11 Sept. 62 | 25 | 2 | Pe, Pp | Irr.<br>Dom,S | 22,000 | Chemical analysis |
| 3248-1333-1 | Near Km. 37.8<br>Public Well | - | 30.35 | Dug | - | Q | 28.85 | 2 Oct. 62 | - | - | - | Dom,S | 2,000 | - |
| 3249-1331-1 | Cabila Enshia, S. of Km 32<br>Larbi ben Fergiani | - | 13.56 | Dug | - | Q | 13.52 | 4 Aug. 53 | - | - | - | Dry | - | - |

Table 6.--Drillers logs of wells in the Qarahbulli area.

Well 3242-1336-1
(OPDL well no. 70)

Altitude 85 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, yellowish-red | 8 | 8 |
| Clay, sandy ("tin") | 9 | 17 |
| Clay, sandy, with gravel | 3 | 20 |
| Clay, yellow, with sandy clay | 7 | 27 |
| Clay, plastic, yellow | 5 | 32 |
| Gravel with fossils | 5 | 37 |
| Clay, scaly, yellow | 4 | 41 |
| Limestone, clayey. Water-bearing | 1 | 42 |
| Clay, yellow | 6 | 48 |
| Conglomerate | 1 | 49 |
| Miocene strata: | | |
| Clay, grayish-green | 9 | 58 |
| Limestone, grayish-white, fossiliferous | 3 | 61 |
| Clay, green | 12 | 73 |
| Clay, slightly scaly, green | 9 | 82 |
| Limestone, white | 6 | 88 |
| Clay, green | 13 | 101 |
| Limestone, hard | 4 | 105 |
| Clay, green, with limestone beds | 13 | 118 |
| Limestone | 3 | 121 |
| Clay, green | 5 | 126 |
| Limestone | 4 | 130 |
| Clay, green | 22 | 152 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3242-1336-1
(OPDL well no. 70) Altitude 85 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Mesozoic rocks: | | |
| Limestone, white | 30 | 182 |
| Sand, loose | 1 | 183 |
| Limestone, arenaceous, white | 14 | 197 |
| Sand, loose. Salty water | 2 | 199 |
| Sandstone, with sand and gravel | 24 | 223 |
| Clay, reddish | 8 | 231 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3242-1336-2
(USOM well no. 27)

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, red | 26 | 26 |
| Limestone, reddish | 6 | 32 |
| Limestone, hard | 5 | 37 |
| Gravel (?) | 3 | 40 |
| Miocene strata: | | |
| Clay, white | 4 | 44 |
| Limestone, clayey | 6 | 50 |
| Sandstone, quartz, and white limestone | 13 | 63 |
| Clay, sandy, green | 19 | 82 |
| Clay, yellow | 15 | 95 |
| Limestone, soft, gray | 10 | 105 |
| Limestone, hard | 5 | 110 |
| Clay, sandy, green | 26 | 136 |
| Mesozoic rocks: | | |
| Limestone, gray, with clay strata | 20 | 156 |
| Sandstone, quartz, calcareous, white | 3 | 159 |
| Limestone, gray | 3 | 162 |
| Limestone, hard | 4 | 166 |
| Limestone, gray | 6 | 172 |
| Sand, quartz, white. Water at 174 m. | 6 | 178 |
| Clay, scaly, yellow | 6 | 184 |
| Limestone, gray, with strata of green scaly clay | 20 | 204 |
| Limestone, soft, and strata of red clay | 10 | 214 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3242-1338-1
(OPDL well no. 69) Altitude 85 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, quartz, pink, with fragments of limestone----- | 10 | 10 |
| Limestone, arenaceous, soft------------------------ | 5 | 15 |
| Sand, quartz, pink, loosely cemented---------------- | 8 | 23 |
| Caliche ("Crostone"), sandy, clayey---------------- | 5 | 28 |
| Limestone, clayey, yellow-red---------------------- | 4 | 32 |
| Clay, yellowish-brown------------------------------ | 2 | 34 |
| Limestone, arenaceous, white, and yellowish-brown clay. Water from 41 to 43 m---------------------- | 9 | 43 |
| Miocene strata: | | |
| Clay, sandy, yellow-------------------------------- | 17 | 60 |
| Clay, dark green, fossiliferous-------------------- | 3 | 63 |
| Limestone, arenaceous, soft, white----------------- | 3 | 66 |
| Clay, dark green, fossiliferous-------------------- | 4 | 70 |
| Conglomerate, clayey, yellow----------------------- | 2 | 72 |
| Sandstone, quartz, calcareous, white--------------- | 7 | 79 |
| Clay, grayish-green -------------------------------- | 18 | 97 |
| Marl, greenish-gray, fossiliferous----------------- | 5 | 102 |
| Clay, grayish-green -------------------------------- | 9 | 111 |
| Marl, greenish-gray, fossiliferous----------------- | 9 | 120 |
| Clay, green, with thin sand layers----------------- | 3 | 123 |
| Clay, somewhat marly, fossiliferous---------------- | 8 | 131 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3242-1338-1
(OPDL well no. 69) Altitude 85 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Mesozoic rocks: | | |
| Limestone, marly, fossiliferous, with pyrite | 19 | 150 |
| Limestone, siliceous, gray | 28 | 178 |
| Clay, red and green | 5 | 183 |
| Limestone, siliceous, hard, gray | 12 | 195 |
| Clay, red and green | 3 | 198 |
| Limestone, siliceous, hard, gray. Salty water; static water level 28 m; yield 16 $m^3$/hr | 21 | 219 |
| Clay, green and red | 3 | 222 |
| Limestone, thin bedded, clayey, gray, and red and gray clay | 8 | 230 |
| Clay, gray | 6 | 236 |
| Limestone, siliceous, hard, gray | 7 | 243 |
| Clay, gray | 3 | 246 |
| Sandstone, gray, with thin clay layers | 54 | 300 |
| Clay, red and green | 3 | 303 |
| Sandstone, grayish-white | 23 | 326 |
| Clay, green | 1 | 327 |
| Sandstone, grayish-white | 11 | 338 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3242-1339-3
(USOM well no. 29)

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Sand, red | 6 | 6 |
| Sand, quartz, white | 5 | 11 |
| Limestone, hard | 7 | 18 |
| Clay, yellow | 6 | 24 |
| Clay, sandy, green | 11 | 35 |
| Clay, green | 15 | 50 |
| Sandstone, quartz, calcareous, white | 19 | 69 |
| Limestone, clayey | 19 | 88 |
| Limestone, hard, with clay strata | 32 | 120 |
| Clay, green | 5 | 125 |
| Limestone, clayey, with hard and soft streaks | 19 | 144 |
| Clay, sandy, green. Water at 168 m | 25 | 169 |
| Sand, quartz, white. Water-bearing | 5 | 174 |
| Clay, green | 4 | 178 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1336-3
(USOM well no. 25)

Altitude 50 m. ±

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, red | 5 | 5 |
| Sand, fine, with limy pebbles | 3 | 8 |
| Sand, limy | 10 | 18 |
| Limestone, sandy, stratified | 3 | 21 |
| Sandstone, bedded | 11 | 32 |
| Clay, green, with sandy beds | 14 | 46 |
| Limestone | 1 | 47 |
| Miocene strata: | | |
| Clay, plastic, green, with sand layers | 38 | 85 |
| Sand, gray | 1 | 86 |
| Clay, plastic, blue | 3 | -89 |
| Sand, gray | 4 | 93 |
| Clay, scaly, white, with sandy layers | 5 | 98 |
| Conglomerate | 4 | 102 |
| Clay, scaly, dark blue | 6 | 108 |
| Sand, gray | 4 | 112 |
| Clay, scaly, dark blue, with sandy layers | 16 | 128 |
| Conglomerate | 6 | 134 |
| Sandstone, gray, with white siliceous sand layers. Water-bearing | 10 | 144 |
| Sandstone, gray | 3 | 147 |
| Clay, scaly, blue | 7 | 154 |
| Sandstone, fossiliferous, with white sandy layers | 7 | 161 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1336-3
(USOM well no. 25) Altitude 50 m. ±

| Lithologic description | Thickness (meters) | Depth (meters) |
|---|---|---|
| No record. Water from 134 to 144 m | 167 | 167 |
| Clay, gray | 7 | 174 |
| Sandstone, gray. Water-bearing | 4 | 178 |
| Clay, yellow | 3 | 181 |
| Limestone, yellowish | 5 | 186 |
| Clay, scaly, red | 7 | 193 |
| Sandstone, gray, and white quartz sand. Water from 199 to 211 m | 19 | 212 |
| Clay, greenish | 1 | 213 |
| Limestone, gray, fossiliferous. Water from 234 to 244 m | 31 | 244 |
| Sandstone, spongy, white. Water from 244 to 250 m | 18 | 262 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1336-4 Altitude 55 m. ±

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, with strata of silt | 19 | 19 |
| Limestone, with gravelly strata | 12 | 31 |
| Sand, quartz, bedded | 2 | 33 |
| Sandstone, with white limestone strata | 17 | 50 |
| Miocene strata: | | |
| Clay, with white sand layers | 9 | 59 |
| Sandstone, porous, white, with beds of limestone | 12 | 71 |
| Clay, plastic, yellow, with sandy beds | 10 | 81 |
| Clay, sandy, ashy-gray | 17 | 98 |
| Sandstone, porous, gray | 5 | 103 |
| Clay, scaly, blue | 12 | 115 |
| Sand, bedded, gray | 3 | 118 |
| Clay, porous, gray, with fossils | 12 | 130 |
| Sandstone, porous | 6 | 136 |
| Sandstone, coarse, gravelly | 11 | 147 |
| Clay, scaly, with sand | 9 | 156 |
| Sand, bedded, white, with fossils | 13 | 169 |
| Clay, scaly, red | 7 | 176 |
| Clay, plastic, red, with sand beds | 3 | 179 |
| Limestone, dark | 5 | 184 |
| Clay, plastic, red | 6 | 190 |
| Sandstone, with soft layers | 10 | 200 |
| Limestone, dark | 20 | 220 |
| Limestone, dark, with clayey strata | 12 | 232 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1336-4 Altitude 55 m. ±

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Sandstone, with limy layers------------------------ | 15 | 247 |
| Sandstone, soft, porous, white---------------------- | 21 | 268 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1339-2
(OPDL well no. 59) Altitude 52 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
| --- | --- | --- |
| Quaternary deposits: | | |
| Sand, siliceous, limy, red | 7 | 7 |
| Sand, limy, with hard layers | 14 | 24 |
| Limestone, light-colored, fossiliferous | 7 | 31 |
| Limestone, light-colored, with oyster shells | 16 | 47 |
| Miocene strata: | | |
| Clay, green, with fossil fragments | 25 | 72 |
| Sand, limy, gray | 3 | 75 |
| Limestone | 0.5 | 75.5 |
| Marl, gray, fossiliferous | 7.5 | 83 |
| Clay, green, with fossiliferous limestone strata | 11 | 94 |
| Clay, green, with fossils | 15 | 109 |
| Limestone, light colored, with fossils. Water-bearing | 6 | 115 |
| Sandstone, limy, light-colored | 7 | 122 |
| Sandstone, quartz, siliceous | 13 | 135 |
| Limestone with strata of clay and sandstone | 18 | 153 |
| Limestone, sandy. Water-bearing | 10 | 163 |
| Limestone, yellow, with hard strata | 4 | 167 |
| Limestone, gray | 4 | 171 |
| Limestone, sandy, light-colored | 8 | 179 |
| Clay, gray | 2 | 181 |
| Clay, sandy, gray | 2 | 183 |
| Limestone with strata of clay | 10 | 193 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1341-1
(OPDL well no. 19) Altitude 50 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, surficial | 2 | 2 |
| Sandstone, quartz, limy, soft | 20 | 22 |
| Limestone and sandstone strata. Water at 22 to 25 m | 8 | 30 |
| Clay, sandy, greenish, with fossils | 5 | 35 |
| Limestone, fossiliferous. Water from 35 to 41m | 6 | 41 |
| Miocene strata: | | |
| Clay, very sandy, fossiliferous | 19 | 60 |
| Limestone, clayey, green, gray, fossils | 9 | 69 |
| Clay, sandy, green | 24 | 93 |
| Sand, limy. Water-bearing | 2 | 95 |
| Limestone, sandy. Water-bearing | 2 | 97 |
| Sand, limy, thin-bedded. Water-bearing | 5 | 102 |
| Sandstone, quartz, soft. Water from 102 to 112 m | 18 | 120 |
| Clay, green | 5 | 125 |
| Limestone, marly, and clay | 5 | 130 |
| Limestone | 3 | 133 |
| Clay, scaly | 2 | 135 |
| Sandstone and quartz sand strata. Water from 135 to 187 m | 32 | 187 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1346-1
(OPDL well no. 11) Altitude 60 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sandstone, clayey, rosy---------------------------- | 20 | 20 |
| Conglomerate, limestone, greenish-white------------- | 6 | 26 |
| Limestone, compact, brownish-green------------------ | 2 | 28 |
| Limestone, soft, clay, yellow----------------------- | 5 | 33 |
| Sandstone, quartz, clean, yellow. Water at 33 m; static water level 31 m---------------------------- | 4 | 37 |
| Miocene strata: | | |
| Limestone, marly, whitish-green with fossils-------- | 3 | 40 |
| Limestone, sandy, yellow, micro-fossils------------- | 7 | 47 |
| Clay, green, with fragments of limestone------------ | 6 | 53 |
| Clay, slightly sandy, with limestone fragments------ | 4 | 57 |
| Sand, clayey, gray-green---------------------------- | 5 | 62 |
| Clay, green----------------------------------------- | 8 | 70 |
| Sand, clayey, gray-green---------------------------- | 2 | 72 |
| Clay, green----------------------------------------- | 13 | 85 |
| Sand, fine-grained, limy with thin green clay beds-- | 23 | 108 |
| Sandstone, quartz, fine-grained, gray-green--------- | 22 | 130 |
| Sandstone, quartz, coarse-grained, white. Water 130 to 138 m; static water level 20 m--------------- | 8 | 138 |
| Sandstone, quartz, friable, gray and yellow--------- | 13 | 151 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1346-1
(OPDL well no. 11) Altitude 60 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Limestone, arenaceous, white | 3 | 154 |
| Sand, quartz, yellow, and yellow sandstone. Water; static water level at 14.5 m; yield 45 $m^3$/hr | 10 | 164 |
| Sandstone, quartz, thin-bedded, yellow | 35 | 199 |
| Mesozoic rocks: | | |
| Sandstone, friable, bituminous | 2 | 201 |
| Marl, schisty, green and red | 2 | 203 |
| Limestone, marly, compact, gray | 3 | 206 |
| Limestone, marly, gray-green, with nodules of pyrite | 12 | 218 |
| Marl, clayey, schisty, green | 3 | 221 |
| Limestone, siliceous, hard, gray | 12 | 233 |
| Sandstone, friable, fine-grained, gray | 33 | 266 |
| Limestone, marly, gray. Water from 266 to 272 m; static water level 14.5 m | 6 | 272 |
| Limestone, marly, lead-gray with thin clay beds | 16 | 288 |
| Limestone, hard with very thin sandstone beds | 20 | 308 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1356-1
(OPDL well no. 18) Altitude 55 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, red | 5 | 5 |
| Limestone, sandy, clayey, spongy, red | 37 | 42 |
| Sandstone, friable, yellow. Water at 42 m | 4 | 46 |
| Miocene strata: | | |
| Limestone, marly, yellowish-white with pebbles | 9 | 55 |
| Sandstone, friable, coarse-grained, yellowish | 7 | 62 |
| Limestone, sandy, spongy, yellow, fossiliferous | 6 | 68 |
| Sandstone, friable, yellow, with fossils | 19 | 87 |
| Limestone, sandy, marly, fossiliferous | 4 | 91 |
| Sandstone, quartz, very friable, yellowish-red. Water at 98 to 111 m | 54 | 145 |
| Marl, limy, dark gray, with thin sandstone layers | 31 | 176 |
| Sandstone, thin-bedded, gray. Water at 176 m | 19 | 195 |
| Mesozoic rocks: | | |
| Limestone, sandy, gray | 20 | 215 |
| Clay, marly, gray, with limestone beds | 13 | 228 |
| Sandstone, marly, gray. Water from 228 m to 239 m | 35 | 263 |
| Limestone, sandy, marly, gray, fractured | 9 | 272 |
| Clay, gray, with a little sand | 24 | 296 |
| Marl, clayey, gray | 10 | 306 |
| Clay, very sandy, gray | 11 | 317 |
| Marl, very sandy, compact, vuggy, gray | 17 | 334 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3243-1356-1
(OPDL well no. 18) Altitude 55 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Sandstone, thin-bedded, limy, gray. Water from 339 m | 8 | 342 |
| Limestone, very tenaceous, dark | 8 | 350 |
| Marl, limy, gray | 1 | 351 |
| Limestone, cherty, dark-gray | 16 | 367 |
| Marl, yellowish | 3 | 370 |
| Marl, limy, gray | 8 | 378 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3244-1337-1
(USOM well no. 3)

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Sand, clayey, red with thin limestone bed at 10 m----- | 15.5 | 15.5 |
| Sand, clayey with interbedded limestone strata-------- | 12.0 | 27.5 |
| Sandstone, with strata of yellow clay. Water at 27 m------------------------------------------ | 2.5 | 30 |
| Sandstone with limestone strata---------------------- | 3 | 33 |
| Clay, yellow, with limestone strata------------------ | 10 | 43 |
| Sandstone with beds of clayey limestone-------------- | 4 | 47 |
| Clay, sandy, green with limestone strata------------- | 27 | 74 |
| Limestone, soft, gray, fossiliferous----------------- | 3 | 77 |
| Clay, green------------------------------------------ | 13 | 90 |
| Clay, scaly, green with limestone strata. Water from 90 to 95 m---------------------------------- | 46 | 136 |
| Sandy, quartz. Water-bearing------------------------ | 5 | 141 |
| Conglomerate, hard----------------------------------- | 2 | 143 |
| Limestone, soft, with clay strata-------------------- | 8 | 151 |
| Sand, quartz. Water-bearing------------------------- | 1 | 152 |
| Limestone, soft, with quartz sand. Water-bearing----- | 7 | 159 |
| Sand. Water-bearing--------------------------------- | 6 | 165 |
| Limestone, soft, gray-------------------------------- | 7 | 172 |
| Limestone, hard-------------------------------------- | 3 | 175 |
| Limestone, soft, gray-------------------------------- | 5.5 | 180.5 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3244-1337-2

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Sand, dune, red | 6 | 6 |
| Sand, clayey, red | 14 | 20 |
| Limestone, hard | 7 | 27 |
| Clay, yellow | 9 | 36 |
| No record | 4 | 42 |
| Limestone with clay beds | 7 | 49 |
| Clay, green, with thin beds of sandstone and scaly clay | 18 | 67 |
| Clay, green, with sandy clay beds | 10 | 77 |
| Clay, green, with gray sandstone beds | 17 | 94 |
| Clay, scaly, and gray limestone beds | 13 | 107 |
| Clay, green | 4 | 111 |
| Limestone, soft, fossiliferous, with some clay beds | 27 | 138 |
| Limestone, hard, yellow | 11 | 149 |
| Clay, yellow | 3 | 152 |
| Clay, and beds of white sand and sandstone | 17 | 169 |
| Clay with gray sandstone beds | 10 | 179 |
| Limestone | 1 | 180 |
| Clay, hard, green | 1 | 181 |
| Rock, hard, with beds of dark clay | 10 | 191 |
| Clay, black and green with beds of hard clayey limestone | 3 | 194 |
| Clay, hard, dark with beds of hard limestone | 5 | 199 |
| Limestone, hard, black | 4 | 203 |
| Limestone, hard, white with beds of sandstone | 13 | 216 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3244-1337-3
(USOM well no. 2)

Altitude 45 m. ±

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, dune | 3 | 3 |
| Sandstone | 16 | 19 |
| Sandstone, calcareous, thin-bedded. Water-bearing | 19 | 38 |
| Sandstone, clayey, green | 4 | 42 |
| Miocene strata: | | |
| Clay, yellow | 15 | 57 |
| Clay, plastic | 25 | 82 |
| Clay with thin limestone and sandstone layers. Water at 90 m | 67 | 149 |
| Limestone, siliceous, hard, with strata of plastic clay. Water at 182 m | 41 | 190 |
| Clay, scaly, and hard rock | 10 | 200 |
| Limestone, hard, with beds of clay. | 20 | 220 |
| Clay, calcareous | 62 | 282 |
| Limestone, siliceous, and scaly clay | 6 | 288 |
| Clay, calcareous, plastic, scaly | 25 | 313 |
| Rock, siliceous | 9 | 322 |
| Limestone, with strata of scaly clay | 16 | 338 |
| Limestone, hard, with scaly clay. Water at 340 m | 51 | 389 |
| Mesozoic rocks: | | |
| Rock, siliceous, hard | 3 | 392 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3244-1337-3
(USOM well no. 2)

Altitude 45 m. ±

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Clay, scaly, and siliceous limestone----------------- | 2 | 394 |
| Rock, siliceous-------------------------------------- | 10 | 404 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3244-1337-4
(USOM well no. 21)

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Sand | 8 | 8 |
| Sand, clayey | 7 | 15 |
| Limestone | 1 | 16 |
| Clay, sandy | 2 | 18 |
| Sandstone. Water from 19 to 21 m | 2 | 20 |
| Limestone | 3 | 23 |
| Sand, clayey | 3 | 26 |
| Clay, light-colored with limestone | 9 | 35 |
| Sandstone, grayish and white sand. Water from 35 to 40 m | 6 | 41 |
| Clay, yellow and gray | 29 | 70 |
| Clay, bluish with thin sandstone strata | 5 | 75 |
| Clay, scaly, bluish | 2 | 77 |
| Sandstone, gray and limestone | 4 | 81 |
| Clay, scaly, green | 10 | 91 |
| Sandstone, porous, gray. Water-bearing | 2 | 93 |
| Clay, bluish with thin sandstone beds | 19 | 112 |
| Sandstone | 6 | 118 |
| Sandstone, porous, and gray sand. Water from 118 to 124 m | 4 | 124 |
| Clay, scaly, gray | 16 | 140 |
| Sandstone, gray and sand. Water-bearing | 4 | 144 |
| Limestone, yellowish | 6 | 150 |
| Clay | 7 | 157 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3244-1337-4
(USOM well no. 21)

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Sandstone, compact, gray with sand. Water from 157 to 175; yield 150 $m^3$/hr | 18 | 175 |
| Clay, yellow | 4 | 179 |
| Limestone, hard, dark | 3 | 182 |
| Clay, gray | 3 | 185 |
| Limestone, hard, dark, with thin strata of gray clay | 9 | 194 |
| Limestone, clayey, hard, dark | 6 | 200 |
| Clay, green | 2 | 202 |
| Sandstone, grayish. Water from 203 to 206 m | 5 | 207 |
| Clay, scaly, green | 2 | 209 |
| Sandstone, gray | 6 | 215 |
| Clay, hard, scaly | 2 | 217 |
| Sandstone, yellowish, and yellow sand. Water flow 250 $m^3$/hr | 4 | 221 |
| Clay, scaly, blue | 1 | 222 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3245-1337-2
(OPDL well no. 89) Altitude 35 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, dune | 13 | 13 |
| Sand, clayey and layers of yellow clay | 2 | 15 |
| Clay, soft and clayey sand (tin) | 3 | 18 |
| Limestone, reddish. Water at 18 m | 2 | 20 |
| Limestone and yellow clay | 5 | 25 |
| Conglomerate | 1 | 26 |
| Clay, sand, reddish-yellow | 2 | 28 |
| Miocene strata: | | |
| Limestone, hard, fissured, with soft clay | 4 | 32 |
| Clay, yellow, with limestone strata | 4 | 36 |
| Limestone | 6 | 42 |
| Clay, soft | 6 | 48 |
| Limestone, fissured, hard | 5 | 53 |
| Clay, scaly, green | 25 | 78 |
| Limestone, hard | 4 | 82 |
| Clay, scaly, green | 3 | 85 |
| Limestone, hard, white | 8 | 93 |
| Clay, green | 6 | 99 |
| Limestone, hard, compact | 5 | 104 |
| Clay, scaly, green | 6 | 110 |
| Limestone, hard, compact. Water at 115 m | 12 | 122 |
| Clay, scaly, green | 4 | 126 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3245-1337-2
(OPDL well no. 89) Altitude 35 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Limestone, fissured, hard | 2 | 128 |
| Clay, green | 1 | 129 |
| Limestone, fissured, hard | 19 | 148 |
| Limestone, fissured, dark gray | 7 | 155 |
| Sand and gravel | 1 | 156 |
| Conglomerate and gravel, hard. Flowing water at 163 m. Static head 14.5 m above land surface | 9 | 165 |
| Limestone and sand | 4 | 169 |
| Limestone, soft, white | 6 | 175 |
| Limestone, clayey, gray | 10 | 185 |
| Sand | 3 | 188 |
| Limestone, siliceous, slightly hard | 1 | 189 |

Table 6.--Drillers logs of wells in the Qarahbulli area cont'd.

Well 3245-1342-2
(OPDL well no. 82)

Altitude 40 m.

| Lithologic Description | Thickness (meters) | Depth (meters) |
|---|---|---|
| Quaternary deposits: | | |
| Sand, reddish | 12 | 12 |
| Clay, sandy, reddish | 8 | 20 |
| Limestone, white. Water from 24 to 26 m | 6 | 26 |
| Clay, yellow, with gravel and fossils | 11 | 37 |
| Miocene strata: | | |
| Clay, green | 22 | 59 |
| Limestone | 3 | 62 |
| Clay, green | 7 | 69 |
| Limestone, with green clay beds | 34 | 103 |
| Limestone, hard, fractured, white. Water at 132 m | 44 | 147 |
| Sand, loose. Water; static water level 2.5 m | 5 | 152 |
| Limestone, white with soft beds. Water at 163 m; static water level 2.5 m | 32 | 184 |
| Limestone, hard, fissured with clay beds | 21 | 205 |
| Clay, scaly | 1 | 206 |
| Limestone, hard | 58 | 264 |

من عمق يتراوح بين ٣٠ و ٤٠ متراً تملك نوعية كيماوية صالحة بوجه عام للاستهلاك الزراعي والمنزلي . وتتوفر ايضاً المياه الارتوازية في الطبقات المائية العميقة في صخور الميوسين بالاخص في ناحية القصبة .

تتخزن المياه في طبقات منطقة القرهبلي عن طريق ارتشاح مياه الامطار المحلية وعن المجاري الجوفية المتسربة من الجنوب . وان معدل التفريغ الناتج عن عمليات سحب المياه بالمضخات وعن المياه المتدفقة من الابار الارتوازية ، وقد يبلغ هذا المعدل نحو تسعة ملايين متراً مكعباً بالسنة ، زد على ذلك التفريغ الطبيعي فانه يفوق معدل كمية المياه التي تتخزن في الطبقات على الاقل في المناطق المعمرة . فبناءً على ذلك فان مستوى سطح المياه في المناطق المعمرة هو بحالة انخفاض حالي (١٩٦٣) على معدل يتراوح بين ١,٠ و ٢,٠ المتر بالسنة . اما انخفاض الضغط المائي الساكن لمياه الطبقات الارتوازية التي تتبع الى الميوسيني فيمكن انه يتجاوز نصف المتر بالسنة .

تنصرف مياه هذه المنطقة من اعالي جبل نفوسة وباتجاه شمالي في بعض ستة سواقي اوازهر موقتة ناقلة المياه السطحية عقب هطول المطر الغزير لتسكبها في البحر بالاخص في اشهر الشتاء . اما مناخ هذه المنطقة فهو شبه جاف ويتميز بقلة وقوع الامطار (٢١١ مليمتر بالسنة في قصر القرهبلي) كما وبشدة التبخر واتساع مدى معدل الحرارة .

تنحصر اكثر المزارع في هذه المنطقة الزراعية في البقعة المنبسطة الواقعة بين كثبان الرمل الساحلية والكثبان الابعد منها نحو داخل البلاد . يجري الانماء الزراعي بنشاط يتراوح من عمليات واسعة النطاق حيث تستعمل بها معدات زراعية حديثة يعمل بها في مراكز الاختبار الزراعية الخاصة للحكومة وعدد من المزارع الايطالية وما بقي من المزارع الصغيرة الاهلية . ويتوقف نمو اكثر المزروعات على الري من المياه الجوفية انما تكفي مياه الامطار لزراعة الشعير وبساتين العنب والزيتون واشجار اخرى .

تقع منطقة القرهبلي جيولوجياً فوق تكوين رباعي وميوسيني ينحدر باتجاه شمالي ويتألفا من حجر الكلس والرمل والطين الذي يقع بدوره فوق صخور العهد الميزوزوئي . وتغطي طبقة الرمل وحجر الكلس التابعة الى العصر الرباعي قسماً كبيراً من المياه الجوفية المستعملة حالياً في المنطقة . اما المياه المستخرجة من هذه الطبقات

# موارد المياه الجوفية لمنطقة القرهبللي في ولاية طرابلس

# المملكة الليبية المتحدة

وضع

وليم أوجلبي وهادي علي طرهوني

## ملخص

تبلغ مساحة المنطقة المشمولة في هذا التقرير نحو ٤٠٠ كيلومتر مربع وتقع على الشاطئ الجنوبي من البحر الابيض المتوسط. وتنحدر ارض هذه المنطقة على وجه عام باتجاه شمالي نحو البحر الذي يحده كثبان الرمل الساحلي والمتماسك. ويقع ما بين الكثبان الساحلية ونطاق من رمال شبه متحركة يمتد على طول الطرف الجنوبي من المنطقة بقعة ارض مسطحة يبلغ عرضها خمسة كيلومترات ويتخللها كثبان رملية مستقرة.

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## في ولاية طرابلس
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طرابلس ، ليبيا
تشرين الثاني (نوفمبر) ١٩٦٢

الولايات المتحدة الأمريكية
وزارة الداخلية
مصلحة المساحة الجيولوجية

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## المملكة الليبية المتحدة

أعد هذا التقرير بالتعاون مع الحكومة الليبية
وتحت رعاية بعثة وكالة التنمية الدولية الأمريكية إلى ليبيا

تقرير مفتوح